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January

Current Problems in the Sensitometry of Color Materials and Processes

By Franklin C. Williams

The methods of sensitometry of color materials and processes are specialized developments of the methods of black-and-white sensitometry. The nature of the individual material and its intended use govern the specifications of the operations of exposing, processing, density measurement, and interpretation of results. Apparatus and techniques now available are adequate for important applications of sensitometry in the manufacture and use of color materials. Current research is refining existing methods of sensitometric investigation and yielding more significant test results.

Interest in the sensitometry of color materials and processes has grown rapidly in the motion picture industry, especially as the film user rather than the film manufacturer has become involved in processing, printing and other laboratory phases of color-film production. In laboratory operations involved in production of black-and-white motion pictures, sensitometric methods have found important uses. It is reasonable to expect that similar or even greater benefits from their use may be found in work with color motion pictures. Certainly, color-film manufacturers have found color sensitometry useful to the point of necessity. Sensitometric methods of investigation and control have played an essential part in the development, production and processing of the wide variety of sensitized color materials which are now available. The extent to which the usefulness of color sensitometry can soon be broadened is indicated by certain aspects of the present state of the science and by developments which are now in progress. It is the intent of this paper to present a brief view of this state, and of certain current developments, with respect to activities in the plants and laboratories of the Eastman Kodak Co.

The general purpose of sensitometric investigation is the establishment of useful relationships among the elements of the chain of operations which result in a photographic image; or rather, finally, to relate the elements of image formation to the impression which the photographic image forms in the mind of the observer. Sensitometric tests usually are required to show how the quality of an image is dependent on exposure, on processing, or on the characteristics of the materials used. The re-

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Communication No. 1361 from the Kodak Research Laboratories, a paper by Franklin C. Williams, Research Laboratory, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y. It was read by Dr. W. T. Hanson, Jr., of Eastman Kodak Co. on October 11, 1949, at the Society's Convention in Hollywood, Calif.

lationships among these and other elements are described in terms of physical quantities. Sensitometry must, therefore, provide accurate and practical means of making the required physical measurements. It must also select and specify what kind of measurement should be made in order that the results be most significant. It must further provide systematic interpretation of the results. Not all of these things can be done at once. To date, development of the science of color sensitometry has emphasized specification of a few basic kinds of measurement, and development of accurate and dependable means of making them. Only during the past few years has vigorous development of systematic interpretation of the results of these measurements been under way.

In order that sensitometric testing be practical, a further requirement must be recognized: The test must be simple. It is for this reason that so much of the sensitometry of black-and-white materials has been reduced to relationships between log exposure and image density. This relationship, usually expressed in the classic curve of Hurter and Driffield, which is itself a model of simplicity, is derived from an irreducible minimum of straightforward operations—exposure, processing and determination of image density. A surprisingly complete knowledge of the photographic properties of a film can be derived from such a test if it is properly specified and conducted. It is natural that similar tests should be tried as the basis of the sensitometry of color materials and processes. Such trials have been adequately successful, so that most of the procedures of color sensitometry that are now in use are special adaptations of procedures originally successful in the sensitometry of black-and-white materials.

This adaptation of the procedures of the sensitometry of black-and-white materials has required throughout careful examination and usually extensive revisions of the specification of each element of sensitometric operation. Furthermore, particularly in specifying the objectives of density measurement, new concepts have had to be developed. A review of these revisions, developments and some of the problems of color sensitometry can be made by examining the elements of routine testing procedure in the order of their occurrence.

Sensitometric Exposures

Since exposure of the film is the first step of the routine, first met are problems of knowing and of specifying what test exposures should be made, and how to make them. The images of color films are, of course, sensitively dependent upon the quality of the exposing light. In color-film testing, therefore, that quality must be extremely well controlled. It must also be carefully chosen. In the film plane of a camera, a different quality of light exists at least at every differently colored point of the image. The response of the film to every one of these different qualities of light may be important. No one quality of light, therefore, can possibly furnish a complete test of the color-reproducing abilities of the film. An infinite set of qualities would be required. But in attempting to reduce tests to forms which are both simple and significant, effort is continuously applied toward specifying, for routine tests, a small number of test colors which may test the film adequately. The exposing-light qualities which represent these colors are generally chosen for one, or both, of two purposes. Some colors are used because they, and therefore their reproductions, are pictorially important. Tests using these colors give directly specific but limited information about the color-reproducing abilities of the film. Other exposures may not represent picture elements at all, but are chosen to give basic information about exposure-image relationships. From these relationships,

the sensitometrist can determine indirectly certain general information about the color-reproducing abilities of the film.

In sensitometric testing, both kinds of exposure are regularly used. Use of exposures which permit product appraisal by direct physical or psychophysical measurements of color reproduction has recently been considerably improved. Work by Brown, MacAdam,[1] and others is extending the data of color discrimination in relationships involving both chromaticity and luminance. This is essential if we are to make quantitative comparisons of color reproductions under practical conditions, which generally involve approximations in both chromaticity and luminance. In the Eastman Kodak Co.'s Color Control Dept., a research group working under R. M. Evans is engaged in the study of the psychophysical and psychological factors involved in the perception of colored objects. Their findings are giving us a much better understanding of the influences of these factors in the evaluation of color reproduction fidelity. Valuable data on the relative photographic importance of colors are coming from statistical analysis of the subject content of customers' pictures. Although the results of these researches have as yet been applied only to product-development work, they will soon find their way into routine testing procedures.

Eventually, the reproduction criteria arising from such work will permit systematic choice of the second kind of test colors—those which may not be critically important in themselves but which will provide sensitive and significant indicators of general reproduction quality. With one exception, these colors cannot yet be chosen systematically. The exception is the color gray. Although the intrinsic importance of accurate reproduction of gray is debatable, a "gray-scale test" is a routine procedure in sensitometric testing of practically every kind of color film made. Years of testing have shown that it is a dependable, sensitive indicator of many important features of the color reproduction characteristics of a film.

A sensitometric gray scale on a color film is the result of exposing the film to a series of intensities of white light. The gray-scale exposure, therefore, must be made with the kind of light which white or gray objects place on the film under conditions of normal use. More exact definition describes the white or gray objects as spectrally nonselective, diffusely reflecting objects. Specifying the conditions of "normal use" requires some investigation of the radiant energy source and of spectrally selective factors in the photographic system.

For example, in exposures made with artificial light, the quality of light in gray-object images is primarily determined by the original source, such as a tungsten lamp, but it is also importantly affected by spectral selectivity of the reflectors and lenses of the lighting units and by selective absorption in the camera lens. It cannot properly be simulated in the laboratory by simply matching the energy distribution of the unmodified lamp source. A special lamp-filter combination is required. Similarly, in exposures made with natural daylight, the white-light quality is dependent upon several factors. These include the position of the sun, the portion of sky effective as illuminant, the atmospheric conditions prevailing throughout the sky, the orientation of the subject with respect to the sky, the degree and nature of reflections by nearby objects, flare light, lens absorptions and other minor factors. The design of sensitometer light sources must include consideration of these factors. We now have good approximations for some of the required light qualities; these include artificial daylight and sources duplicating tungsten lighting qualities. But the newer light sources

in use in motion picture practice and elsewhere are difficult to match in a sensitometer, especially since sensitometer sources must be stable and adequately powerful as well as spectroradiometrically correct. This problem is receiving considerable attention. For its solution, better spectroradiometric data are required than are now available, and an instrument for this purpose is under construction in our laboratory.

The actual exposure of film to the light quality selected can be made in sensitometers already developed for sensitometry of black-and-white materials. The great importance in color sensitometry of making the exposure represent normal conditions of time and intensity, in order to avoid errors arising from failure of the reciprocity law, has led to development of special models of this apparatus, but no radically new principles have been introduced.

Sensitometric Processing

The second set of problems in color-film sensitometry is met in the processing of the sensitometric test films. It has long been a first principle of sensitometric practice that the processing of test samples must satisfy two requirements: It must be repeatable with excellent precision, and it must be correct in kind. Probably no requirements of sensitometric color testing are more difficult to meet than these. Correct and invariable sensitometric color processing is difficult, but where such processing must be done, it is being done; frequently there is no really acceptable alternative course. Improved methods of using production processes for sensitometric tests are constantly under development, and improvement has been made, especially in treatment of the data, but variable processing can be used for evaluation of film characteristics only by making some sort of repeated comparison with one or more selected "check" films, simultaneously processed to furnish a basis of reference. This familiar procedure offers a frequently useful substitute for direct measurement but also a somewhat treacherous one, since an adjustment based on one process-film combination often is not applicable to another. Modern methods of statistical analysis furnish means of recognizing such cases in a properly designed experiment, but not of correcting the data.

The application of advanced statistical methods to interpretation of sensitometric data is a course of development in color sensitometry which deserves early recognition. Statistical methods are receiving wide recognition in industry as a tool especially useful in handling processes of complex variability. In color photography, known variables rarely can be made to operate with complete independence. It is possible, however, by special statistical methods, to extract from complexly variable data significant descriptions of the individual variations. The methods have been reduced to routine forms and are proving of great value in both research and testing operations.

A process which is repeatable but incorrect also presents difficulties. If the testing process does not accurately represent the normal treatment of the film, appraisal of the product is at least uncertain and is sometimes impossible either by direct measurement or by comparison with a "check" film. Furthermore, considerable experimental evidence indicates that the best, and quite possibly the only, adequate method of maintaining long-time stability in characteristics of film and processing, each independent of the other, is a combination of a stable reference process and extensive chemical analysis. Sensitometric color processing, therefore, is the subject of much research activity. The research involves both special processing apparatus and special processing solutions.

In sensitometry of materials for black-and-white photography, there has

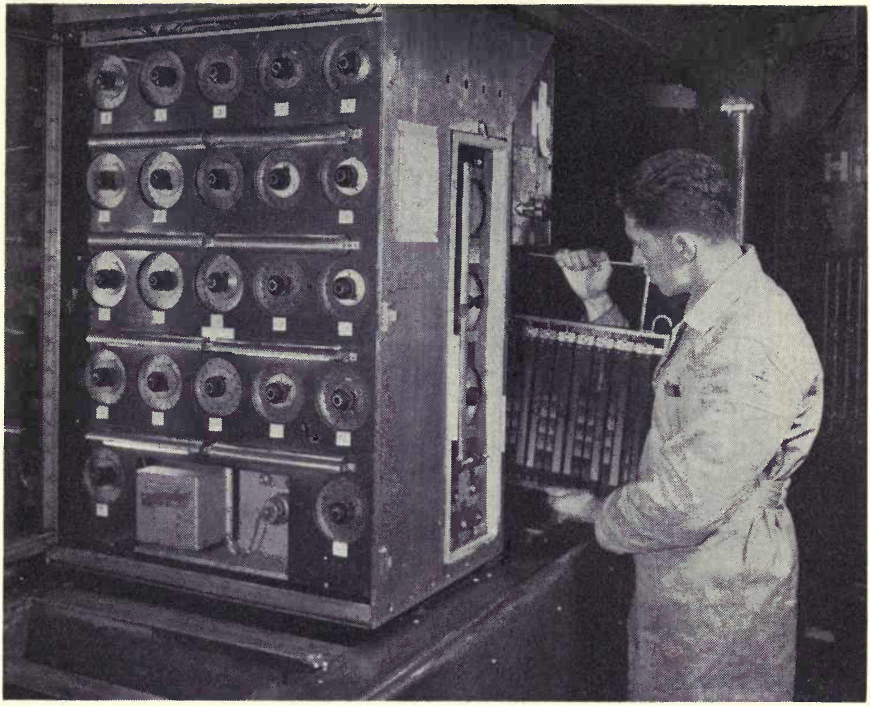

Fig. 1. Automatic machine for processing sensitometric test strips of color films and papers.

been adequate demonstration of the value of processing equipment especially designed for sensitometric testing. The reciprocating-paddle machine described by Jones, Russell and Beacham[2] has been notably successful in providing repeatable processing with excellent uniformity in its treatment of all samples in a particular loading. The principles of this machine have been applied to color processing with good success. Considerable enlargement of the equipment is, however, necessary to make color-processing output comparable with the usual output of black-and-white film. For example, one kind of sensitometric color-processing machine in use in the Film Testing Dept. at Kodak Park is shown in Fig. 1. These machines contain eleven developing tanks and eleven wash tanks; the machines for developing black-and-white film contain only one of each. In the color-film processing machine, the test samples, on racks, are placed in light-tight developing units which are lowered by motor into the tanks. Each machine is equipped with three such developing units. Each unit has an independent set of paddles and an associated drive. The unit of film, paddles and drive travels the length of the machine on an overhead track, then circles back to the starting end for re-use. Each unit carries with it a battery of 22 clock-driven controllers which automatically govern the sequence and duration of the process operations. The degree of agitation, electronically controlled, is widely variable and also is

automatically selected by the controlling panel. The three units, each holding 80 sample strips and operating independently, are spaced far enough apart in the machine to let the operator change processing solutions between units. It is therefore possible to process Kodachrome, Ektachrome and Ektacolor films simultaneously on the same testing machine.

Smaller machines with fewer automatic features are useful in process control if they are designed to provide precisely controlled development. Several such machines have been built and have proved capable of producing processes of good repetition accuracy. It is realized, however, that no sensitometric processing machine yet designed is ideal, particularly in its ability to imitate color processing as done in large continuous film-strip machines. Further improvements along this line are necessary.

The processing machine is no more important than the solutions which go into it and is much more easily made free of undesirable variation. Sensitometric processes must be repeatable not only from day to day, but, if necessary, from year to year. Such repetition can be guaranteed only by identical handling of the film in solutions of identical chemical constitution. A good processing machine will provide identical handling. A perfectly replenished continuous process would provide the identical processing solutions, but, although recent improvements in analytical methods promise to guarantee nearly perfect replenishments, this method has not been entirely satisfactory in sensitometric work. Instead, repeated identity of processing solutions has been accomplished by using, for each test, entirely new solutions mixed from a homogeneous reserve stock of chemicals.

The attainment of chemical identity in processing solutions is not a simple matter. Some solutions used in color processing are sensitive to extremely small changes in amount of ingredients and to variations in mixing procedure. So small a thing as the way in which a dry chemical is poured into the solution can materially affect the sensitometric result. We have found, for example, improved repetition precision when the alkaline ingredients of the solutions are dissolved in nearly the ultimate solution volume, before any oxidizable ingredients are present; otherwise, the amount of oxidation in the high pH region immediately surrounding the dissolving alkali will vary objectionably from batch to batch. Small-volume mixing requires precision weighing, frequently with analytical balances, and liquid measurement with volumetric pipettes. If precision of chemical measurement and handling is adequate, repeatable mixes in one-gallon batches are possible in apparatus like that shown in Fig. 2, a jacketed cone with high-speed turbine homogenizer. It is preferable, however, to mix in larger batches wherever possible. Large-batch mixing is economically feasible only if the solutions can be stored, without deterioration, for later use. We have found that chemical solutions can be stored successfully by segregation of reactive components, and in difficult cases have found it helpful to store solutions just above their freezing point. Tests made throughout the past year have shown that even coupler-developer solutions can be made to maintain unchanged properties for at least three weeks.

When the film samples of a sensitometric test have been exposed and processed, the testing routine requires next that their image densitities be determined. We recognize in color densitometry two classes of density measurement with two distinctly different purposes: One class is called integral densitometry; the other, analytical densitometry. The purpose of integral densitometry is the measure-

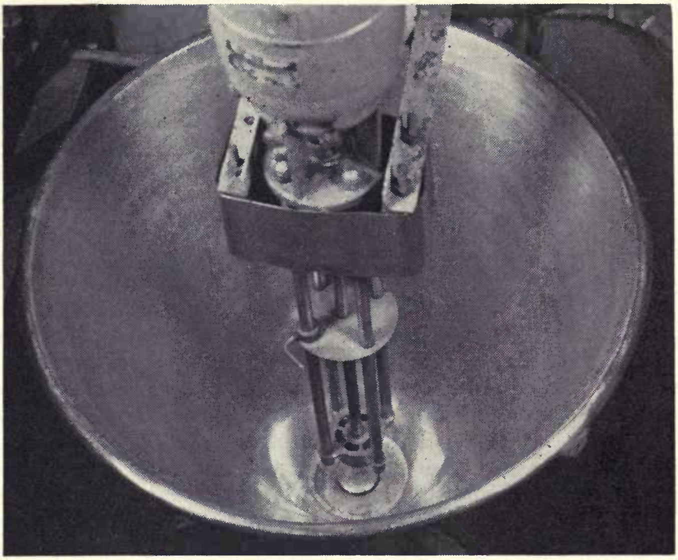

Fig. 2. Jacketed conical mixing vessel and turbine homogenizer for mixing small batches of color-film processing solutions.

ment of the composite, multilayer image to determine some total action, some particular effectiveness of the integrated image absorptions. The purpose of analytical densitometry is the determination of the individual densities of certain components of the image, such as the densities of the individual yellow, magenta and cyan dyes.

Printing Densities

In the sensitometry of color materials to date, the most valuable integral densitometry has been the measurement of printing densities. A color negative, for example, may be printed on a color-print film that has a red-sensitive emulsion, a green-sensitive emulsion, and a blue-sensitive emulsion. The function of the negative is the regulation of the amount of exposure of each of these emulsions. The negative performs this function by absorbing some of the light which would expose these red-, green- and blue-sensitive emulsions. The amounts of the absorptions can be expressed as densities called "printing densities." Since the negative image will usually absorb red, green and blue light unequally, it will have three different printing densities. Each step of a gray scale will, therefore, have three printing densities, and, if these are plotted as a function of log exposure, the gray scale produces three characteristic curves. These are called the "gray-scale printing-density curves." A set of such curves is shown in Fig. 3.

The determination of printing densities by a densitometer requires the use of precisely specified kinds of red, green and blue light. The fundamental requirement is that the printing-density densitometer assign to radiant energies of various wavelengths the same relative importances that would be assigned by the printing system, that is, by the combination of printer light and

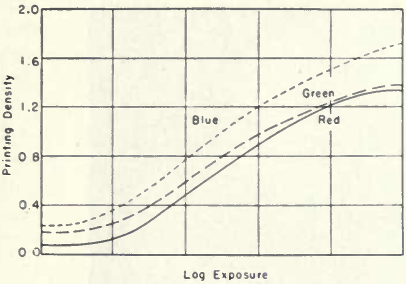

Fig. 3. Printing-density curves of the gray scale of a color-negative material.

print material. In a simple case, if only light of λ 680 mμ were effective in making a red-light print, the printing density of the negative would have to be determined by measurement with only light of λ 680 mμ. In most practical cases, energy of a particular spectral distribution throughout a more or less broad band is effective in printing, and this distribution must be accurately reproduced in the density-measuring instrument. Since the densitometer must determine three printing densities of each image, measuring energy of three such distributions must be readily available. In achieving these distributions, we have thus far managed to obtain adequate accuracy by using optical filters of specially designed transmittance functions. Printing densities so determined have become extremely valuable in product development and control. They are the principal sensitometric measurements used in performance inspection of color-negative materials. For this use, high-speed automatic densitometers have been developed. Figure 4 shows a recent model. Recently, the severe requirements imposed by colored coupler-negative materials have made the design of densitometer filters especially difficult and, as a result, research has been accelerated on the use of other means of spectrum selection. An obvious but difficult means is by disper-

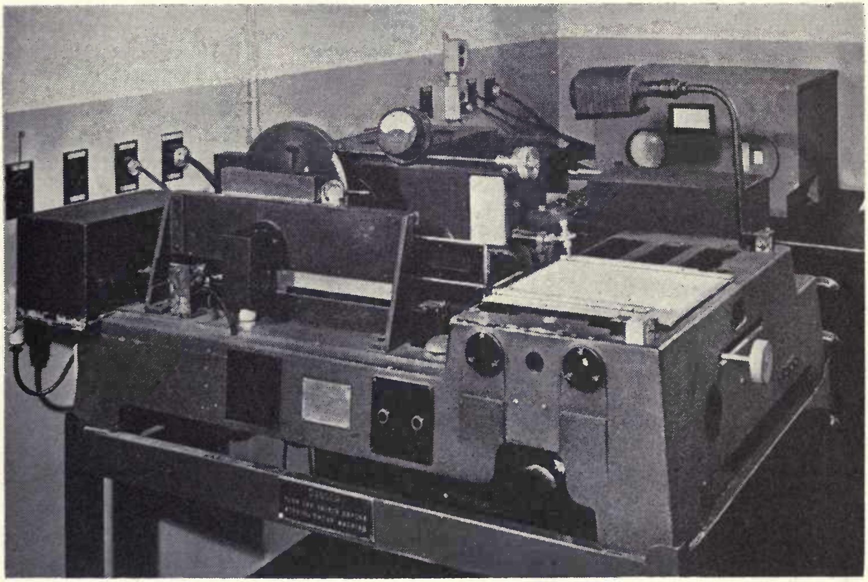

Fig. 4. Automatic recording densitometer for rapid determination of printing densities.

sion of the energy of the densitometer light source into a spectrum image, selection of part of this spectrum by a mask, recombination of the transmitted portion into a homogeneous mixture and use of this energy for the measurements. We have had an instrument of this type under development for several years. The difficulties of obtaining simultaneously the excellent spectral purity and considerable energy required in the measuring beam are quite severe.

Analytical Densities

In some kinds of sensitometric work, image description by means of integral densities is inadequate. Especially in product development and in control of manufacturing and processing is knowledge of the individual dye densities of color images important. In such work, the desired characteristics of a color-film image can be expressed either by specifying its integral densities or by specifying the required densities of its component dyes. If specification is by integral densities, an obtained image can be compared with the desired image by integral densitometry, but, although this will describe the practical effects of any differences, it will not describe the differences in a way that indicates where to apply corrective measures. Wherever means are known by which individual dye deposits can be changed by known amounts in the process of image formation, approaches to the desired image characteristics are made most efficiently if the desired and obtained images are both described in terms of the individual dyes. Such a description is obtained by analytical densitometry and usually consists of a set of equivalent neutral densities. Equivalent neutral density is a unit for systematically expressing the densities of the individual dyes of a subtractive process in terms of their abilities to form grays. As defined by Evans,[3] the equivalent neutral density of a dye deposit in a subtractive color process is the density of the gray that would be formed by adding to that dye deposit the just-required amounts of the other dyes of the process. Figure 5 shows a set of equivalent neutral-density curves. Evans described an instrument for determining equivalent neutral density, but other methods have since been developed for faster determination, less subject to an operator's judgment.

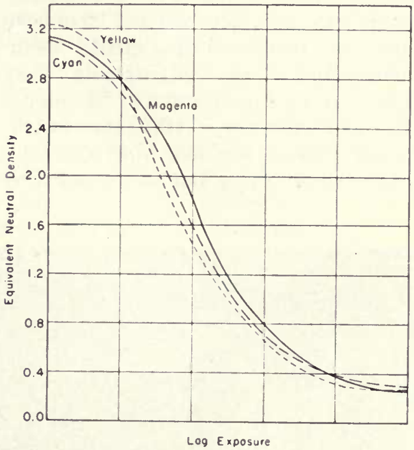

Fig. 5. Equivalent neutral-density curves of the gray scale of a professional sheet-film material.

One method, first described by Heymer and Sundhoff[4] in Germany, has been developed by the Film Testing Dept. in Kodak Park to a point that permits high-speed measurement. It requires an instrument that provides two identical light beams; the sample, in one beam, is synthetically matched by a combination of dye wedges in the other beam. A recent model is shown in Fig. 6. This model automatically makes all adjustments required in the analysis. The theory of analysis with instruments of this type involves fewer simplifying assumptions and approximations than are involved in other methods, but the cost of the instrument is high. Research

in the Kodak Laboratories has been directed toward the development of simpler means of analysis, particularly of one in which the required measurements are densities of the image determined by use of three narrow bands of light, one each in the blue, green and red spectral regions. By a system of coordinate transformation, these three integral densities are made to yield the required equivalent neutral densities. Instruments capable of measuring the integral densities are made commercially by several manufacturers and have been made by many sensitometrists themselves, but these instruments vary widely in their performance characteristics and abilities. Different instruments produce not only different integral density values but also conflicting analytical density values. This condition may be improved by activity of a committee of the American Standards Association which is attempting some standardization of color densitometry. In our laboratory, we use a densitometer of our own design and perform the coordinate transformations by a specially designed electrical analog computer, shown in Fig. 7. Integral density values are placed in it by setting three potentiometer dials. Closing one of the switches in the lower right-hand corner completes a circuit which instantly computes the equivalent neutral-density value of the cyan dye and activates a servo mechanism which rotates the central upper dial to the correct equivalent neutral-density figure. Upon opening the first switch and clos-

Fig. 6. Automatic analytical color densitometer.

ing a second, the magenta equivalent neutral density replaces the cyan-density figure; a third switch causes the yellow equivalent neutral density to appear. Accuracy of the computed transformed density value is better than 0.01.

In this work, as elsewhere in color sensitometry, the elementary theory is simple, but improvements past the elementary point involve labor among complex phenomena. A great deal of recent research on improvement of color-density measurements has been concerned with determining the real significance of image-analysis data. An essential step in this investigation is the derivation of an accurate spectrophotometric description of the minimum set of variables which can be combined to reproduce not only all the colors of which the process is capable but all the spectrophotometric distributions as well. Mathematical procedures for handling this problem have been developed. The analytical components so determined are being used in a study of product and processing variations to determine whether present methods of analysis yield the most significant data possible.

The fact that this work is being done is evidence that development of color sensitometry even now is growing out of its first stage, in which emphasis has been placed on the improvement of precision and accuracy of measurement. It is passing into the next phase, in which measurements, made with techniques of adequate precision and accuracy already achieved, are to be applied to more significant tests. Progress is being made toward the day when sensitometric methods may be as definitive in the specification of color-film quality as they are in the specification of quality of materials for black-and-white photography. That day has not yet come, but a great deal of progress has already been made.

Present-day tests are valuable tests. They require precise application of a carefully chosen exposure, a correct, precisely controlled color process, and densitometry by an accurate, rapid instrument which measures a specific kind of density particularly suited to derivation of significant information. By use of these solidly founded elements, it is possible to draw sensitometric curves on which we can make significant, though still experimental, measurements of contrasts, gradients, speeds, densities, exposure latitude and other important features of the material. These things are being done hundreds of times every day, furnishing information which is reliable and definitive.

Color sensitometry, therefore, stands now in a solid position of usefulness, with a good deal of accomplishment already behind it. Its immediate problems are those of improvement and exploitation of demonstrated techniques while pursuing a background development of new methods. The course of development will, in the near future as in the past, be considerably influenced by the demands of new products and new applications.

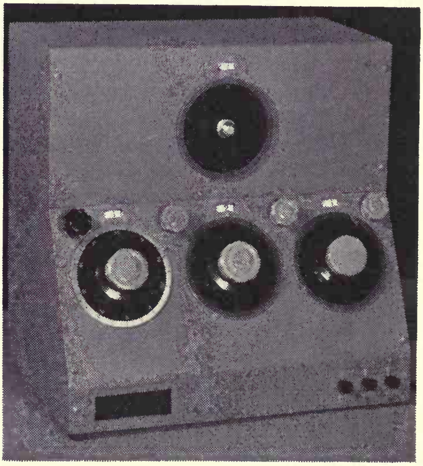

Fig. 7. Electrical analog computer for determining equivalent neutral densities from narrow-band integral densities.

References

1. W. R. J. Brown and D. L. MacAdam, "Visual sensitivities to combined chromaticity and luminance differences," *J. Opt. Soc. Amer.*, vol. 39, pp. 808–834, Oct. 1949.
2. L. A. Jones, M. E. Russell and H. R. Beacham, "A developing machine for sensitometric work," *Jour. SMPE*, vol. 28, pp. 73–94, Jan. 1937.
3. R. M. Evans, "A color densitometer for subtractive processes," *Jour. SMPE*, vol. 31, 194–201, Aug. 1938.
4. G. Heymer and D. Sundhoff, "Über die Messung der Gradation von Farbenfilmen," *Veröffentl. wiss. Zentral-Lab. phot. Abt. Agfa*, vol. 5, pp. 62–76, 1937.

Discussion

Dr. Gundelfinger (Chairman of the Session), to Dr. Hanson who delivered Mr. Williams's paper: Doctor, I might just point out one thing. I believe that densitometer wedges must consist, must they not, of the same components that are used in the color processes?

Dr. Hanson: Yes, they must be composed of those components that are used in the process.

Dr. Gaspar: Is the power-type agitation the generally adopted method?

Dr. Hanson: Yes, that is true. Both of the machines that are shown in the slides have paddle-type agitation. In both machines the paddles are variable in speed and in the larger machine, in pitch, so the distance from the surface of the film to the paddle may be varied.

Dr. Gaspar: Do they move parallel to the film?

Dr. Hanson: They move across a 35-mm film. I might add that the general type of machine that has been used has been described by Jones, Russell and Beacham in the Society's Journal [ref. 2 above].

A Direct-Reading Equivalent Densitometer

By A. F. Thiels

The definition of equivalent density of a primary color of a multilayer color film is given and a direct-reading photoelectric equivalent densitometer is described. The method of operation of the instrument is explained and the basic features of the electronic circuit and the optical and mechanical layouts are given. The apparatus has made it possible to make direct measurements of the density of any one primary color of a color film without being affected by the presence, if any, of other primaries.

Present-day color films consist principally of three emulsion layers in each of which, after exposure and color development, a color is formed: yellow in the blue-sensitive top layer, magenta in the green-sensitive middle layer and blue-green (cyan) in the red-sensitive bottom layer. These are called primary colors and will be referred to as follows:

j, yellow*
m, magenta
c, cyan (blue-green)

In the subtractive color composition practically all color variations can be reproduced by varying the relative proportions of the color density of the primary colors. In order to measure these color quantities in the sensitometry of color film, the equivalent density precept has come into current use.[1,2]

The equivalent density of a primary color is the neutral density which is obtained when the required quantities of two other primaries are added to the primary color to form a visually neutral gray. The determination of equivalent densities is therefore always linked to a selection of three primary colors, and is, furthermore, dependent on the lighting condition under which the film is visually examined.

The significance of this precept becomes more obvious when it is taken into consideration that a gray step wedge exposed in an intensity sensitometer should reproduce a wedge having all its steps neutral gray. The characteristic sensitometric curves of such a gray step wedge expressed in equivalent densities will by definition coincide (Fig. 1A). If, however, some of the steps are not neutral gray, the curves will no longer coincide; for example,

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A contribution submitted March 22, 1950, by A. F. Thiels, Gevaert Photo-Products, Antwerp, Belgium.

*Designation of yellow by *j* follows the practice of Bingham[4] in which footnote 2 on p. 371 notes: The letters *J* and *j* are used instead of *Y* and *y* to represent densities in the yellow layer in order to avoid conflict with the notation of additive colorimetry.

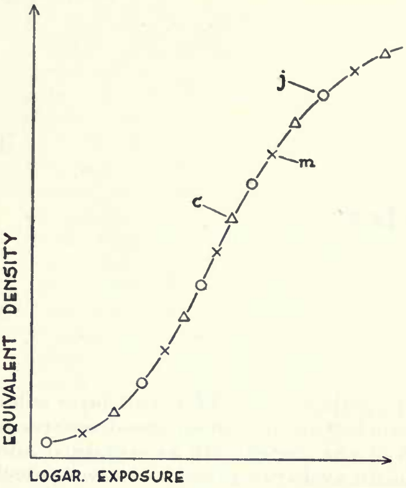

Fig. 1A. Characteristic sensitometric curves of a well-balanced color step wedge.

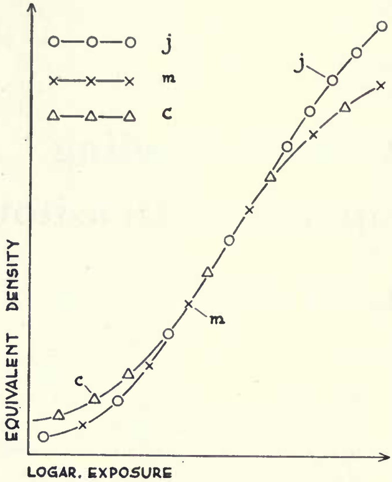

Fig. 1B. Characteristic sensitometric curves of an unbalanced color step wedge.

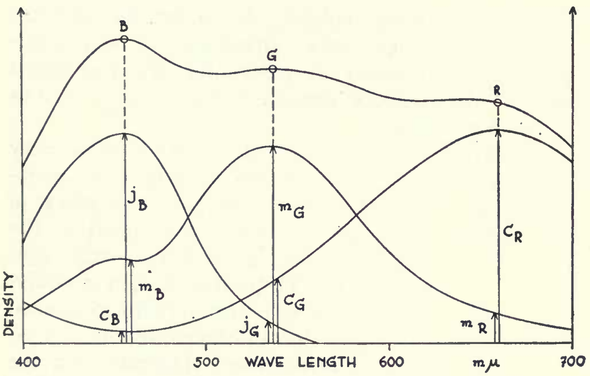

Fig. 2. Spectral diagram of a typical selection of primary colors.

when they have a touch of blue, the "yellow equivalent curve" will be lowest. The amount by which the color balance has been disturbed can be read directly from the curves.

For instance, on a step wedge of which sensitometric curves are as shown in Fig. 1B, the lowest densities have a bluish hue, the medium ones are neutral and the highest densities will have a brownish tint because of the predominance of yellow.

For the purpose of determining the characteristic curve of each layer, it is not possible to separate the different layers of the material and measurements must be carried out on the multilayer film as a whole. Different methods can be used in order to arrive at more or less accurate evaluations of the sensitometric curves of the individual layers: (a) by the conversion of measurements at three different wavelengths[3,4]; (b) by the recomposition of the color by means of three standardized primary color filters.[2,5]

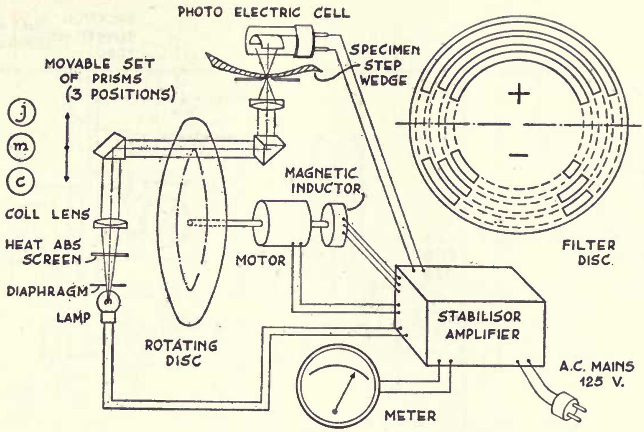

Fig. 3. General layout of the equivalent densitometer.

These methods are slow and, in addition to elaborate calculations, require specially trained personnel. Hence, methods had to be evolved by which direct determination could be obtained of sensitometric characteristics of the complete multilayer color film. Such a method is afforded by the equivalent densitometer.

The Equivalent Densitometer

To facilitate the understanding of its operation, a study of the spectral diagram of a subtractive color layer will be of great assistance. Figure 2 shows the spectral-density curves of a typical selection of primary colors and also the density curve of the composition formed by them. The information which is sought is the proportion of j_B of the yellow primary in the multilayer. Actually only the total density (through a narrow-cut blue filter) can be measured:

$$B = j_B + m_B + c_B$$

If it were possible to subtract automatically the proportions of the secondary absorptions, m_B and c_B, from the total measurement, the desired purpose would be attained.

Assuming a linear relationship between the secondary and the peak absorption of a primary color (which elementarily proves to be correct), thus, m_B/m_G = constant and c_B/c_R = constant with similar notations for other secondary absorptions, it may be inferred [see references 3 and 5] that the equivalent density, j, m and c of the three primaries, is found by the solution of the linear system of three equations:

$$\begin{aligned} j &= k_{11}B - k_{12}G - k_{13}R \\ m &= -k_{21}B + k_{22}G - k_{23}R \\ c &= -k_{31}B - k_{32}G + k_{33}R \end{aligned} \qquad \text{(I)}$$

B, G and R are total measurements through narrow-cut blue, green and red filters. The constants, $k_{11}, \ldots, k_{33}$, are positive numbers which are obtained from the absorption curves of the primary colors. The equivalent densitometer automatically solves this problem.

General Scheme

After passing through a heat-absorbing screen, the light of a stabilized underrated low-voltage lamp (Fig. 3) is collimated by a lens into a parallel beam which, by means of an adjustable set of totally reflecting prisms, is directed through one of the concentrically

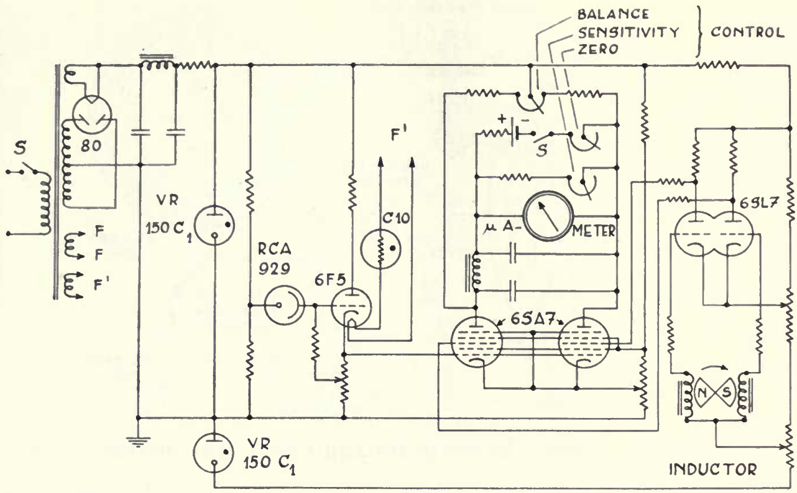

Fig. 4. Simplified layout of the electrical circuit of the equivalent densitometer.

arranged filter sets situated in a revolving disc. Through a second lens the rays are then converged and, after traversing a circular aperture and the sample strip to be measured, are directed onto the cathode of a photoelectric cell.

When the prisms are adjusted to direct the rays through the outer set of filters situated in the revolving disc, the equivalent density of the yellow primary can be measured in this position.

As the disc revolves at a constant speed of 2000 rpm, regular flashes of blue, green and red light strike the photoelectric cell and the currents generated in the latter are amplified and conducted to the measuring instrument. By means of the polarity reverser (magnetic inductor) which is mounted on the shaft of the rotating disc, the blue flashes are caused to pass through the d-c meter in a positive direction, the red and green flashes, respectively, in a negative direction. Furthermore, since the lengths of the filter bands are so balanced that after amplification the light impulses are proportional with the constants, k_{11}, k_{12} and k_{13} (shown in the first equation of the linear system I), it is possible to determine the quantity of j. Similarly, the other quantities, m and c, which are the equivalent densities of magenta and cyan, can be determined by adjusting the prisms to the corresponding filter segments of the rotating disc.

At the outset, the "density" of the selective filters was such that the combination of light source, filter and photoelectric cell statically gave identical readings for the three filters. Later it will be seen that, in order to make certain corrections, filter densities which are not always equal were adopted.

Basic Circuit

Figure 4 shows a simplified diagram of the amplifier circuit. The current generated in the photoelectric cell by light impulses is amplified in the first triode tube, of which the upper part of the tube characteristic is used to obtain an almost logarithmic amplification. The grid bias-resistance contributes toward

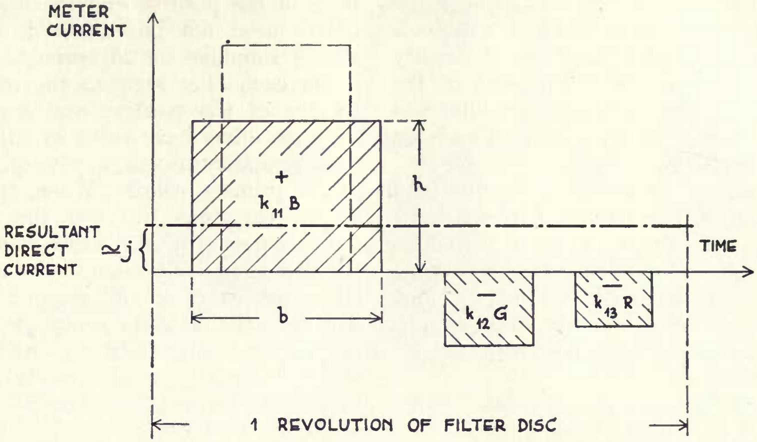

Fig. 5. Diagram of periodic impulses through the meter.

the achievement of this result.[6] The amplified signal is then transmitted to the parallel-coupled control grids of two heptodes. These act as a barrier and during one half revolution of the filter disc the left tube passes the signal, while during the other half revolution the right tube does likewise, in order that the direction of the current through the meter is alternatively reversed. This is attained by directing high square-wave voltages (±40 v) which vary in phase by 180 degrees, to the modulation grids of the heptodes.

The square-wave voltages are generated in the magnetic inductor which is synchronized with the revolving filter disc.* A π-filter only lets pass the resultant direct current thus protecting the meter against excessive alternating currents and eliminating vibration of the needle. The meter is a d-c 100-microammeter of which the scale, 125 mm in length, is calibrated in equivalent densities. The scale reads from 0 to 3. The shunt on the meter is so selected that a quick response of the needle is assured.

It is possible to make an electrical circuit by which a logarithmic amplification is obtained. Such an amplification gives a linear density scale over the whole measurable range.[6] Preference has been given to the adoption of a squared density scale. Although the intervals on this scale become somewhat short at the higher densities, they are nevertheless quite distinct and the accuracy in reading is not affected as is the case with logarithmic scales.

This amplification has the advantage that by an adequate choice of the selective filter densities certain apparent deviations of the Lambert-Beer law can be compensated, e.g., those caused by the curvature of the absorption curves of the selective filters, by fog other than that caused by dye components or by slight variations in the proportion of secondary and peak absorptions of the primary colors in function of density.

In fact, a closer observation of the impulse registration (Fig. 5) reveals, for

* The same result can be obtained by projecting light impulses of determined lengths synchronized with the revolving filter disc onto a set of photoelectric cells. Also, note the description of the improved electronic circuit given at the end of this paper.

example, that the impulse through the meter, $+ k_{11}B$ = surface $h \times b$, depends as much on the quantum of density (height h), which is the sum of the density of the (blue) selective filter and film density, as on the length of the filter (width b).

Changing the density of the filter and its length (while holding $k_{11}B$ constant) moves the operating range of the triode to a different portion of its nonlinear control characteristic. Thus different deviations from linearity could be obtained from the impulses provided by each filter.

For a linear relation between density and meter current, the filter density may be varied providing the length of the filter is properly adjusted so that the surface remains $b \times h = k_{11}B$.* This applies for whatever sample density is placed in front of the photoelectric cell. When the scale is not linear but, for example, squared, deviations will occur.

We shall not go further into these corrections now, but meanwhile it is clear that for constant-density disparities in the film strip, constant-current variations will show on the meter when the relationship is linear, and furthermore, that these constant-density disparities give no constant-current variations over several points of the meter scale, when the relationship ceases to be linear. These deviations allow compensation for the above-mentioned errors and they make the equivalent curves of the three primary colors coincide better.

Calibration of the Apparatus

The lengths of the filters in the circular slits of the disc are adjustable by means of sliding cover plates. The length of dark spaces between filters has no influence on the result because the "barrier tubes" do not allow current to pass when no light strikes the photoelectric cell. Therefore, the dark sections of the positive and the negative halves need not be equalized, which greatly simplifies the adjustment.

For each filter segment the relative lengths of the positive and negative selective filters have to be so adjusted that the apparatus will perceive only one of the primary colors. When, for example, the light traverses the outer filter segment of the disc which measures the yellow equivalent density of a film strip, the meter should respond to a density variation of the yellow primary, but not for density variations of the two other primary colors. By a careful selection of the filters and accurate adjustment of the filter lengths for any density of a primary color to be measured, needle deflections of less than 0.02 are obtained at any position on the scale for density variations of the other two primaries ranging from 0 to 3, no matter whether these densities are placed together or separately in front of the photocell.

After the ratios of lengths of the three filters have been established *within* each filter circle, these ratios must be preserved during an additional adjustment. This adjustment consists of proportional changes in the over-all lengths of the filters in the concentric circles, so that the meter deviations should be identical for the three positions of the reflecting prisms when measuring a visual neutral gray. This adjustment is necessary to make the densities of all three dyes register properly on a single meter scale. To this effect a series of visually neutral gray steps are carefully selected by a light of 3000 K.

The absolute length of the filters is finally established when the shunt rheostat, which is necessary to adjust the meter to zero, just critically damps the meter.

Lastly, the specular density of the neutral gray steps is determined with the aid of an optical densitometer (Martens' Polarisation Photometer) and on the basis of this measurement a scale

* (f.i. the broken-line rectangle)

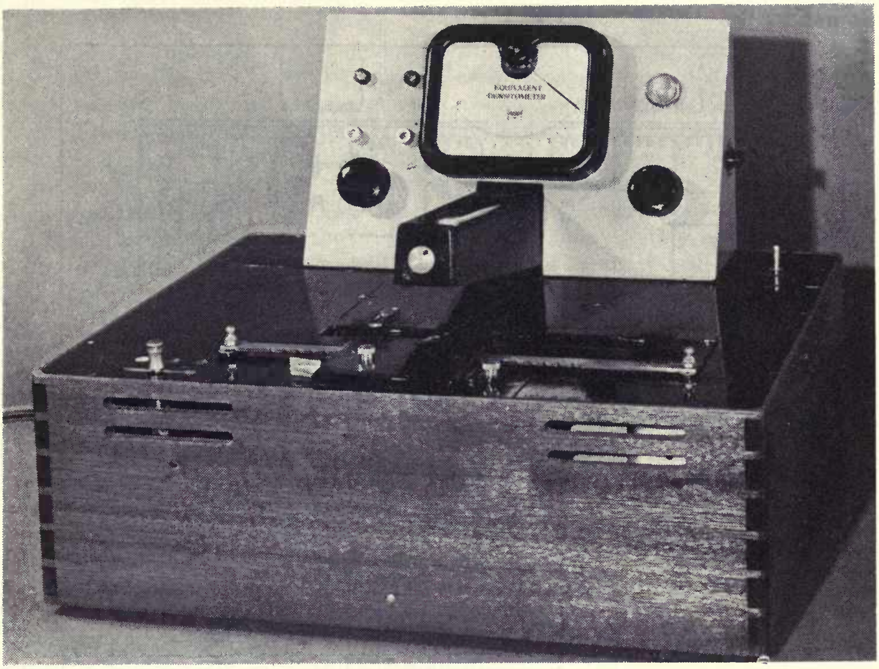

Fig. 6. Practical construction of the instrument.

is calibrated in specular equivalent densities.*

The adjustment of the apparatus is quite simple. The prisms are first aligned with the middle filter segment (measurement of the equivalent magenta). A calibrated filter of density = 3 is inserted in the head of the swivel measuring arm and placed in position in front of the photoelectric cell. By means of the regulator the needle of the meter is set on density 3 on the scale. The calibrating filter is then slid aside and the meter set to zero by a second control. The latter adjustment does not influence the former. The instrument is now ready for use.

The apparatus is fitted with a ratchet-slide which allows the wedge to be advanced layer by layer facing the aperture. This makes it possible to measure the color wedge layer by layer and overcomes the necessity of readjustment of the prisms for each step. The ratchet-slide assures that at every move exactly the same area of the wedge faces the aperture. For routine work the measuring arm can be fixed just above the test wedge.

The filter discs are made interchangeable so that the appropriate disc can be fitted for each set of primary colors. In theory it is possible to change the calibration of the apparatus electrically, but this implies the risk of errors and inaccuracies in the adjustment and therefore preference is given to the interchangeable discs.

The photograph (Fig. 6) shows the practical construction of the instrument.

Stability of the Apparatus

Special care had to be taken with the stability of the apparatus in view of the industrial line fluctuations.

* In this respect, it is not essential that the optical system should fill the requirements of specular measurements.[7]

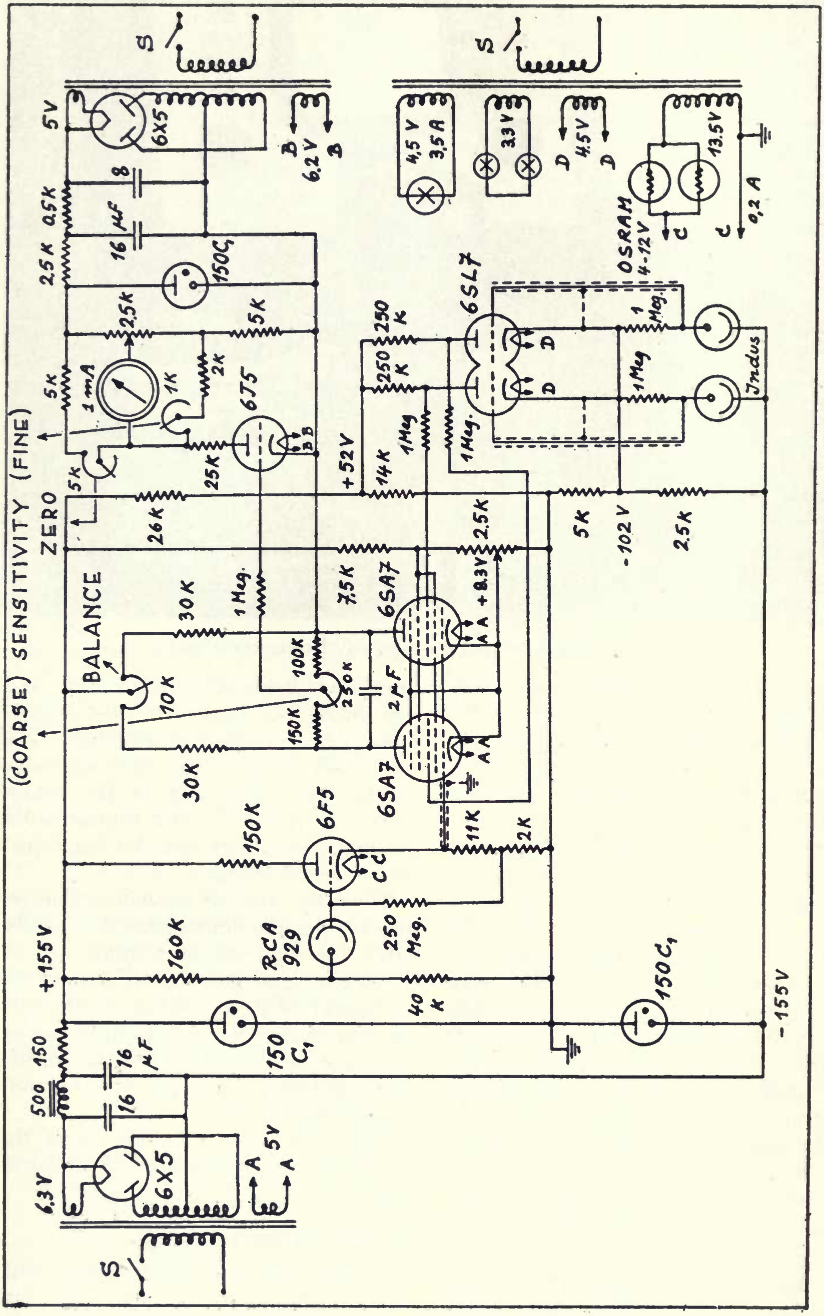
(COARSE) SENSITIVITY (FINE)
ZERO
BALANCE
6X5
6J5
6SA7
6SL7
6F5
RCA 929
OSRAM 4-12V
Indus
+155V
-155V
+52V
-102V
150 C1
150C1
1 mA
S

Figure 7.

With the apparatus under review, line voltage variations can be maintained within ± 1% by the introduction of a magnetic voltage stabilizer on the input line. The built-in voltage-regulator tubes and current regulators assure a stabilization of less than 0.1% for the crucial parts of the circuit. They completely check slow voltage changes over an interval of a few cycles. Short surges, if they occur at the moment when the photoelectric cell receives an impulse, are absorbed by the heavy choke which protects the meter. In order to increase the stability, the filament current of the first triode was reduced to 200 ma and stabilized with a ballast tube. In this way, no readable changes in full-scale deflections are noticeable with line voltage variations from 75 to 140 v (nominal voltage being 125 v). Table I shows a series of measurements of the magenta primary of a gray step wedge for voltages ranging from 135 to 75 v. No additional adjustments were made during the measuring.

Lacking a frequency generator, the systematic examination of the line frequencies is impossible. In practice, however, no effects of frequency variations of the line are experienced between 48.5 and 50.5 periods.

The consumption of the apparatus is 80 w and the warming-up time is about five minutes.

The instrument has been in use in our laboratories for about nine months and proved to be reliable. A standardized neutral wedge was measured every three or four days over a period of approximately two months. The maximum deviation recorded was 0.05, in the region of density = 2. This deviation was partly due to inaccurate positioning of the standard wedge in the ratchet-slide and may partly be attributed to the aging of the tubes and the photoelectric cell (variations in color sensitivity).

Acknowledgment

The author acknowledges the interest and advice of L. A. Meeussen, Gevaert Color-Film Dept., and F. T. Mees, radio-technician; and wishes to express appreciation to H. Verkinderen, Director of Research at the Gevaert Factories, Antwerp, for permission to publish this paper.

References

1. G. Heymer and D. Sundhoff, "Ueber die Messung der Gradation von Farbenfilmen," *Veroffen. Wiss. Zentral-Lab. phot. Abt. Agfa*, vol. 5, pp. 62–76, 1937.
2. R. M. Evans, "A color densitometer for subtractive processes," *Jour. SMPE*, vol. 31, pp. 194–201, Aug. 1938.
3. G. Heymer, *Film und Farbe*, Max Hesseverlag, pp. 25–28, Berlin, 1943.
4. R. H. Bingham, "Sensitometric evaluations of reversible color film," *Jour. SMPE*, vol. 46, pp. 368–378, May 1946.
5. N. Senger, *Film und Farbe*, Max Hesseverlag, p. 13, Berlin, 1943.

Table I. Influence of Line Voltage Variations on the Measurement of the Magenta Primary Dye of a Gray Step Wedge.

Step No.:	1	3	5	7	9	11	13	15	17	19
135 v	.20	.31	.43	.67	1.00	1.30	1.57	1.86	2.22	2.53
125 v	.20	.31	.42	.67	.99	1.30	1.58	1.87	2.22	2.53
115 v	.20	.30	.41	.68	1.00	1.30	1.57	1.86	2.22	2.51
105 v	.20	.30	.42	.66	.99	1.29	1.55	1.85	2.22	2.51
95 v	.20	.31	.41	.67	1.00	1.30	1.56	1.87	2.22	2.52
85 v	.20	.31	.42	.66	1.00	1.31	1.57	1.87	2.23	2.53
75 v	.20	.31	.43	.68	1.00	1.31	1.57	1.86	2.23	2.53

6. M. H. Sweet, "A precision direct-reading densitometer," *Jour. SMPE*, vol. 42, pp. 148–172, Feb. 1942.
7. ASA Z38.2.5 (1946), "American standard for diffuse transmission density," p. 8, American Standards Association, 70 E. 45th St., New York 17.

[*ADDENDUM:* Since this paper was submitted, the author has developed an improved circuit which is reported to have given entirely reliable service during the last half of 1950. The author has kindly supplied the diagram and brief description for inclusion at press time.—*Ed.*]

Improved Electronic Circuit

It is possible to use photoelectric cells to generate the synchronized square wave. As the construction with photoelectric cells, to replace the magnetic inductor, is of more universal practice, we here describe a complete circuit (Fig. 7) showing the disposition of the cells.

The use of photocells makes it possible, in addition, to take the length of the "positive filter" longer than 180° (e.g., "positive filter" 240°—"negative filter" 120°) so that the circumference may be more advantageously utilized.

The addition of an amplifier stage behind the barrier-lamps has the advantage that a more robust meter can be used (1- to 3-ma), whilst the amplifying characteristic of this stage can be so selected that a linear-density scale can be drawn on the dial.

A Versatile Densitometer for Color Films

By A. C. Lapsley and J. P. Weiss

A new densitometer for the analysis of color films reads densities with a narrow wavelength band at any desired wavelength between 350 and 760 mμ. This instrument was constructed utilizing two commercially available units: a Coleman Model 10-S Double Monochromator Spectrophotometer and a Western Electric RA-1100-B Densitometer. It has performed quite satisfactorily during more than two years of continuous service.

RESEARCH STUDIES of color film required an instrument for measuring the spectral densities of dye images. For maximum utility, the instrument had to meet a number of specifications. First, density measurements were to be made with essentially monochromatic illumination. Second, provisions for measuring density at any wavelength were desired, because for research purposes density readings made at the wavelength of maximum absorption of a given dye were most useful. Another requirement was the ability to read to quite high densities, at least 4.0. This requirement was even more important for color densitometry than for black-and-white, since the spectral density of a dye may exceed appreciably the neutral density to which it contributes. Accuracy was another obvious requirement. To measure subtractive dyes accurately at high densities, only a very low percentage of stray white light could be tolerated in the monochromatic beam. Rapid and convenient operation was also specified. The instrument had to be operated by nontechnical personnel with sufficient rapidity to handle a large volume of color-film sensitometric strips. Reliable, trouble-free operation was also highly important.

Since none of the commercially available color-measuring instruments combined all the desired features, it was necessary to design one. In the interests of low design cost and maximum reliability an effort was made to utilize existing, proven components wherever possible.

Description

A special densitometer was constructed, incorporating a modified Coleman Model 10-S DM Spectrophotometer (made by American Instrument Co.) as the light-source unit and a Western Electric RA-1100-B Densitometer as the indicator. To obtain sufficient sensitivity to the radiant energy transmitted by the colored images, it was necessary to use a multiplier photo-

Presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by A. C. Lapsley and J. P. Weiss, Technical Div., Photo Products Dept., E. I. du Pont de Nemours & Co., Inc., Parlin, N.J.

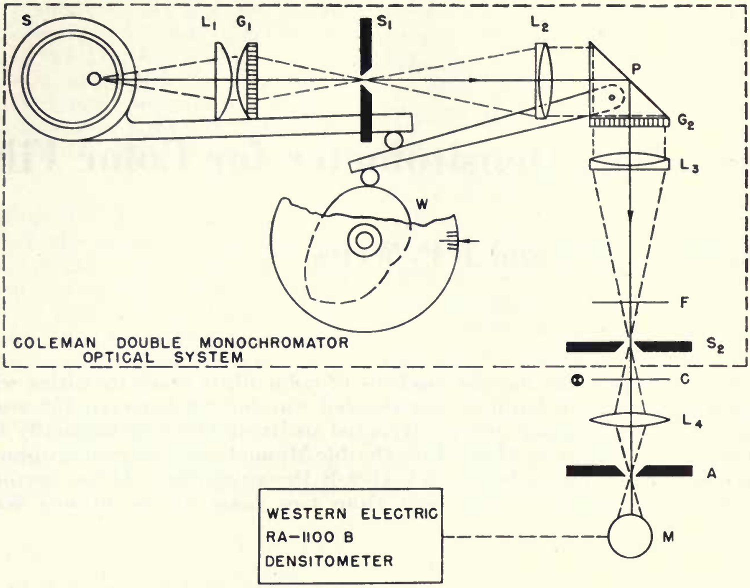

Fig. 1. Schematic layout of Color Densitometer.

Light originating at source S is resolved into monochromatic beam by the diffraction gratings, G_1 and G_2. Exit beam is focused by lens L_4 onto density located at A. Transmitted light is received by multiplier phototube M which is in turn electrically connected to the Western Electric Densitometer.

tube. Direct-current voltage for the phototube was provided by a rectifier and filter operating from the a-c lines.

The schematic diagram of the color densitometer appears as Fig. 1. The portion enclosed within the dotted lines is the original Coleman optical system. The light source, S, is a lamp with a vertical coiled, line filament which acts as the entrance slit of the monochromator. The first transmission grating, G_1, cemented to condenser lens L_1, forms its spectrum across a fixed slit, S_1, which passes a narrow spectral band into the second dispersing system. This light is collimated by lens L_2 and is reflected by a right-angle prism, P, through the second grating, G_2, and is focused on slit S_2 by lens L_3. The desired wavelength is selected by rotating the cam, W, which, linked by arms, swings source-slit S and rotates prism P so that the spectrum is swept across slit S_2, and the same wavelengths pass through both S_1 and S_2 at all times.

Added to the Coleman Spectrophotometer is a filter system, F, to reduce residual stray white light to a negligible amount. While the double grating monochromator passes only a small amount of stray white light, stated as being a fraction of a per cent, the requirement of light purity is very stringent if dye densities up to 4.0 (a transmittance of 0.01%) are to be read. The subtractive dyes used in color photography have fairly narrow absorption bands, roughly one-third the visible spectrum, and they transmit the other two-thirds of the spectrum quite freely. To minimize errors from this cause, the appropriate one of five fairly narrow band-pass filters may be put into the light beam. The transmittance of these

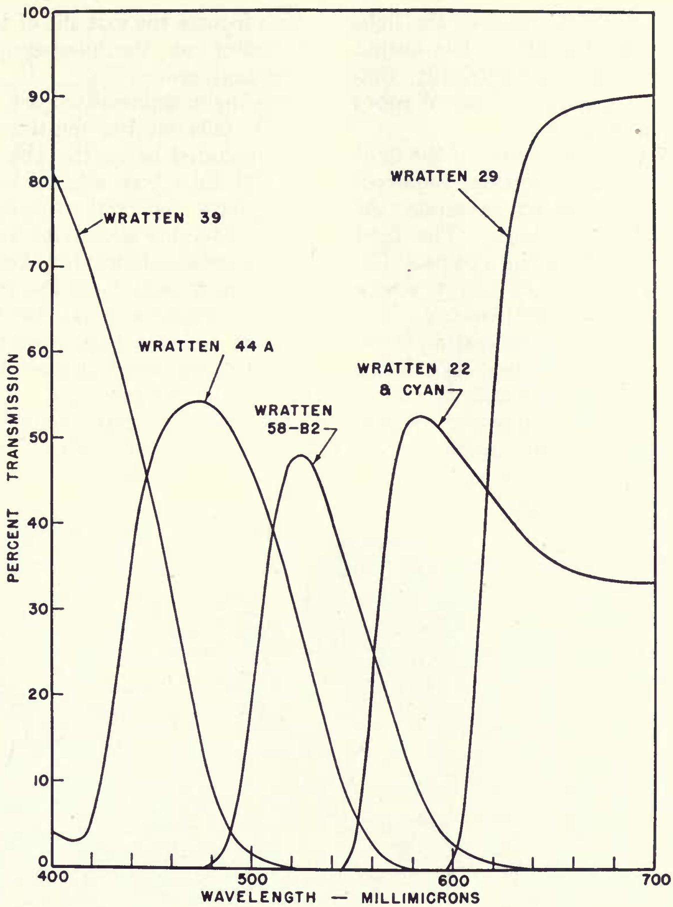

Fig. 2. Transmission curves of auxiliary filter system.
Each filter combination transmits only a limited portion of the spectrum and eliminates the major portion of any stray light that leaks through the monochromator system.

filters is shown in Fig. 2, where it is seen that they give a fairly complete coverage of wavelengths in the 400- to 700-mμ range.

To provide a pulsating signal to the Western Electric amplifier, which is tuned to a frequency of 450 cycles/sec, the light is interrupted by a chopper, C. This consists of a 15-slot disc driven by an 1800-rpm synchronous motor, just as in the original light source of the Western Electric Densitometer.

Additional elements to complete the light-source unit are a lens, L_4, to focus an image of exit slit, S_2, at the film aperture, A, and two mirrors which cause the final image to be oriented properly. The film aperture and the sensitometric strip-holder are identical with those on the Western Electric instrument. The multiplier phototube, M, mounted be-

low the aperture, A, receives the light transmitted by the film. The output of the phototube is electrically connected to the amplifier of the Western Electric Densitometer.

Figure 3 is a photograph of the light source unit with housing removed. The L-shaped casting contains the Coleman optical elements. The light source is at the left of the casting. The knob and dial near the light source comprise the wavelength control. The knob at the right of the casting is for the filter system. Clearly seen is the slotted interrupter disc and its motor. The black housing in front of the disc contains the lens and mirror system which focuses the exit slit of the monochromator on the photographic film being analyzed.

The light transmitted by the film sample falls on the multiplier phototube mounted below the film aperture. A 1P22 tube was selected as having appropriate spectral sensitivity. It has considerable sensitivity at 700 mμ, where response is wanted, but falls off rapidly in sensitivity at about 750 mμ. Infrared response must be kept low since the infrared transmission of most organic dyes might otherwise lead to spurious density readings.

The wiring diagram is shown in Fig. 4. Direct-current voltage for the multi-

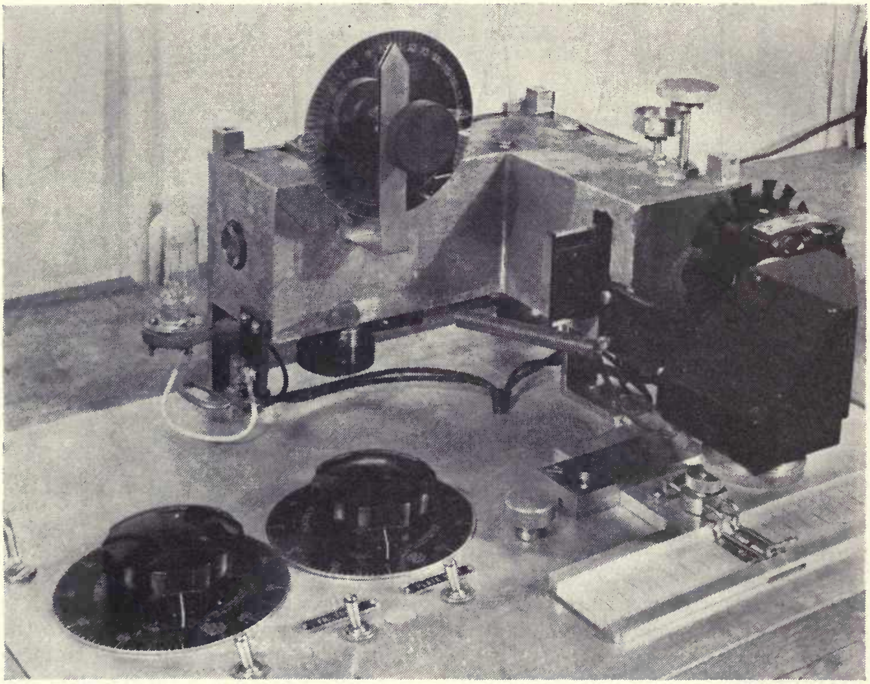

Fig. 3. View of light-source unit with housing removed.

Large casting to the rear contains Coleman double monochromator optics. The motor-slotted disc combination at the exit of the housing serves as a light interrupter which allows an a-c electrical signal to be picked up from the phototube. Housing on the near side of the motor contains a mirror-lens system for focusing and orienting the light from the exit slit onto the density to be analyzed.

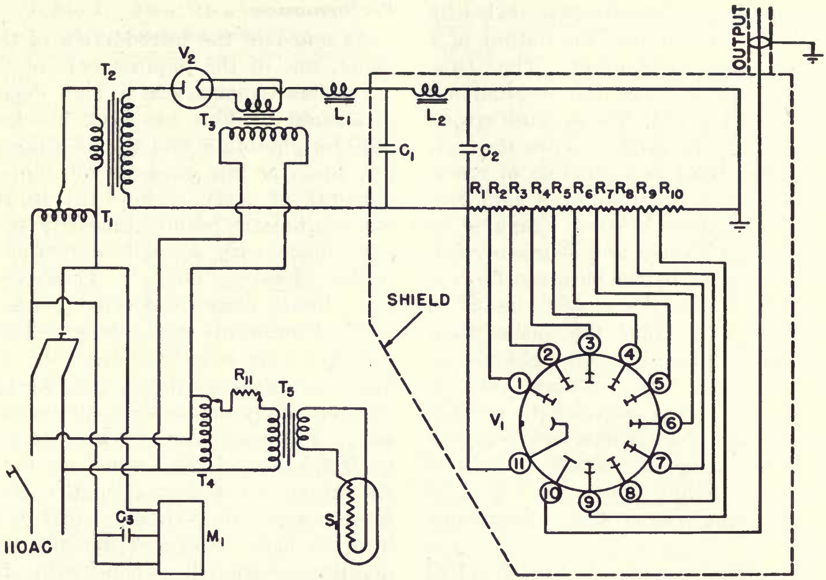

Fig. 4. Wiring diagram of the Color Densitometer.
High voltage supply to the multiplier phototube, V_1, and low voltage supply to the light interrupter motor, M_1, and light source, S_1, are shown.

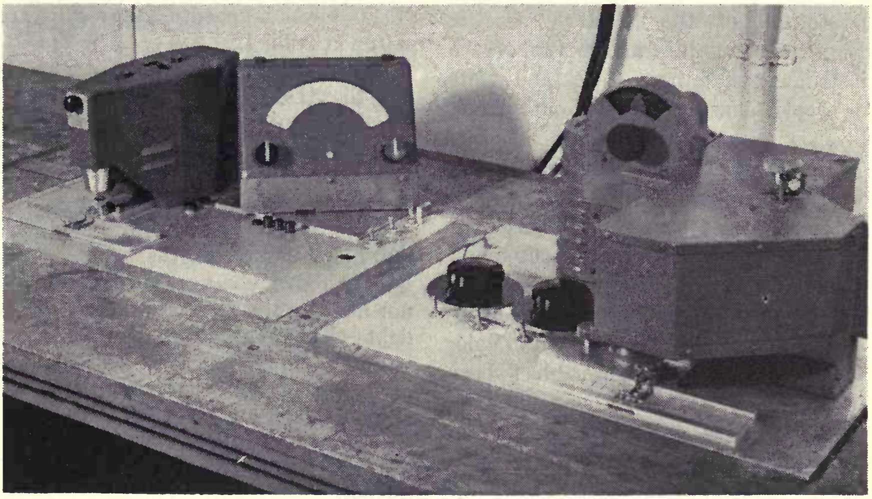

Fig. 5. The mounting of Color and Western Electric Densitometers.
The meter on the Western Electric unit has been rotated to face the Color Densitometer operator.

plier phototube dynodes is provided by rectifying and filtering the output of a high-voltage transformer. The two-section filter reduces the residual a-c signal to a level too low to cause errors, even at high densities. Since the output of the 1P22 as a function of wavelength is quite nonuniform, a gain control independent of that available in the Western Electric amplifier is needed. This is supplied by the autotransformer, T_1, which varies the supply voltage to the 1P22. By doing this rather than varying the intensity of the light source, the maximum signal-to-noise ratio is maintained at any wavelength setting. Line-voltage fluctuations are compensated by using a voltage stabilizer. The other wiring shown in Fig. 4 is for the light source and synchronous motor.

The signal output from the 1P22 phototube is fed directly to the first amplification stage of the Western Electric RA-1100-B Densitometer,* an instrument very well known in the motion picture industry. The connection is made, through a shielded coaxial cable, in parallel with the No. 929 phototube of the Western Electric Densitometer; this allows use of the instrument as either a black-and-white or a color densitometer without switching.

The complete color densitometer assembly is shown in Fig. 5. The monochromatic light source is to the right and the Western Electric Densitometer to the left. It may be noted that the density meter of the latter has been rotated to face the operator of the color densitometer. The meter has been mounted on a column and may be swung to face an operator of either instrument.

*J. G. Frayne and G. R. Crane, "A precision integrating sphere densitometer," *Jour. SMPE*, vol. 35, pp. 184–200, Aug. 1940.

Performance

As noted in the introduction of this paper, one of the requirements of the color densitometer was a high degree of accuracy. This has been checked, both for phototube and amplifier linearity, and for the presence of minute amounts of stray white light in the monochromatic beam. Linearity tests were made with specially constructed neutral density "filters." These were thin brass discs perforated with a series of uniformly spaced holes. Their densities were calculated from the size and spacing of the holes and checked experimentally on an accurate photometer. Two such discs, having densities of 0.495 and 1.015, were on hand. At various selected wavelengths, these filters were individually introduced into the light beam and the indicated densities recorded. Then with the filters removed, the light intensity was reduced until the meter indicated the value recorded for the 1.015 filter. At this light level the two discs were again introduced into the beam and the densities recorded. This process was repeated until an indicated top density of 4.060 was reached. The results are shown in Table I.

Up to the top density of 4.00 it is seen that there is good linearity at wavelengths throughout the visible spectrum. The shouldering that appears at 350 and 760 mμ at high densities is probably the result of phototube noise caused by the high voltage that has to be applied to it at these wavelengths.

The above checks, however, would not indicate the presence of stray white light. This can be serious, for if there is 0.01% unwanted light which is not absorbed by the selective dye, it will cause a density error of 0.002 at a density level of 2.0, 0.02 at a level of 3.0, 0.12 at 3.5 and 0.32 at 4.0. This rapid increase of the error at high densities suggests a ready method of checking. This is to measure the density of two selective absorbers at the level of 2.0

Table I. Densities measured at various wavelengths.

True Density	Wavelengths, mμ				
	350	440	540	700	760
0.495	0.51	0.50	0.495	0.50	0.505
1.015	1.03	1.02	1.025	1.02	1.035
1.510	1.51	1.52	1.52	1.52	1.54
2.030	2.05	2.04	2.04	2.04	2.06
2.525	2.54	2.51	2.54	2.54	2.55
3.045	3.03	3.06	3.065	3.06	3.05
3.540	3.40	3.55	3.55	3.57	3.42
4.060		4.02	4.04	4.01	

Table II. Density checking results.

Wavelength, mμ	Strip 1	Strip 2	Strips 1 & 2 Calc.	Strips 1 & 2 Read
600	1.30	1.18	2.48	2.49
610	1.33	1.21	2.54	2.54
620	1.39	1.27	2.66	2.66
630	1.52	1.37	2.89	2.90
640	1.61	1.44	3.05	3.03
650	1.68	1.51	3.19	3.18
660	1.78	1.58	3.36	3.34
670	1.82	1.63	3.45	3.44
680	1.87	1.66	3.53	3.52
690	1.88	1.67	3.55	3.56
700	1.86	1.65	3.51	3.50

and to measure the density of their combination. Such a test has been carried out on a sample of color film in the wavelength region 600–700 mμ, with the results tabulated in Table II. It is seen that there is no noticeable error caused by stray light.

The color densitometer has given quite trouble-free performance. It has been in daily use for over two years. The only attention required has been occasional replacement of the lamp.

Discussion

M. C. Townsley: Is the receiver which receives the energy after it passes through the film so arranged that it reads diffuse density or is it substantially specular density?

Mr. Lapsley: Actually, it probably reads a combination, but closer to specular density. That is, we don't have any integrating sphere. We use light which is focused onto film and which diverges beyond the film. The phototube is mounted close enough so that it catches all of the light that passes through the film, or at least a major portion of it. This instrument as we built it was designed primarily for color-film work, using dyes which have only a negligible amount of scattering, and it is our opinion, which has been checked up to the limits that we can check, that the density it measures would actually be the specular and diffuse density.

Mr. Townsley: Do you feel that, for a dye material, the specular density and diffuse density are not very different?

Mr. Lapsley: That is correct. We of course could not make measurements on black-and-white film with that instrument, but there would be no point in doing so.

Anonymous: Have you found any difficulty with selective fatiguing of the multiplier phototubes?

Mr. Lapsley: We have not found any difficulty with that as such. Maintenance of a constant relationship of output versus wavelength is not required for proper operation of this instrument. Zero adjustment is convenient and is made for the wavelength selected just before density measurements are made.

Recent Studies on Standardizing the Dubray-Howell Perforation for Universal Application

By W. F. Kelley and W. V. Wolfe

The adoption of safety base film throughout the motion picture industry has required the abandonment of the Bell & Howell perforation for color release prints. This fact presents an opportunity to achieve the long-desired goal of a single standard perforation for negative and positive films in all applications. Tests are described and conclusions reached covering registration problems in the studio, studio laboratory and release laboratory, as well as accelerated and normal release life tests on Dubray-Howell perforated black-and-white prints.

The importance of the perforations on the side of a motion picture film would be difficult to overstate. Those perforations are relied upon for propulsion and registration in every photographic and projection operation in the making and exhibiting of a motion picture. Unfortunately, the importance of these perforations is not understood by a great many people in the industry, and even those who do realize their importance are often inclined toward the philosophy that "what was good enough for my father is good enough for me."

The history of the perforation size and shape is contained in the Journals of this Society and that information was very excellently gathered and presented by the Film Dimensions Committee in the April, 1949, Journal, at which time it was proposed, for the third time, that the Dubray-Howell perforation should be adopted as a universal standard.

Just to review this situation briefly, note that the first accepted standard perforation was the familiar Bell & Howell perforation which, prior to 1923, was standard throughout the industry for both negative and positive use. Because of nonstandard projector sprockets, the inherently weak tear-resistance of the Bell & Howell sprocket was aggravated. A number of the pioneer engineers of the industry and of this Society considered the problem and came up with the present Eastman positive perforation which was accepted throughout the industry for release print purposes. Even at that time, however, there were many voices raised in opposition to a different standard perforation for negative and positive applications.

In 1932 Messrs. Dubray and Howell proposed a perforation combining the

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rectangular shape of the positive perforation with the 0.073-in. height of the negative perforation, thus obtaining the best features of both perforations from the standpoint of existing equipment, registration and projection life. Nevertheless, in 1933 this Society adopted the Eastman positive perforation as the universal standard for both negative and positive film. However, the industry refused to accept this universal standard because it required changing every camera, projector or printer throughout the world.

In 1937 the Subcommittee on Film Perforation Standards recommended that the 1933 standard be withdrawn and again proposed the Dubray-Howell perforation as the universal standard. This report was turned down by the Standards Committee because it was felt at that time that the large amount of background film accumulated in the libraries would prevent the universal perforation from being used.

Beginning in 1947 and continuing since that time, your Film Dimensions Committee, under the chairmanship of Dr. E. K. Carver, has continuously had on its agenda the problem of securing a universal standard perforation acceptable to all of the industry. Tests made by many people predominently supported the early contention of Dubray and Howell that this rectangular perforation with an 0.073-in. height was satisfactory for all negative and positive purposes. M. G. Townsley at Bell & Howell demonstrated in some tests made not long ago that Dubray-Howell perforated film would operate with satisfactory steadiness in a camera equipped with a Bell & Howell full-fitting pilot pin.

This situation might have continued without any conclusion for a long time but for the introduction by Eastman Kodak Co. of the new safety base film. Prior to this time, all of the commercially used color systems employed Bell & Howell perforated release prints because of the need for a high degree of registration in making such prints; but, because the new film base is reported to be somewhat lower in its tear strength than the nitrate film base, two color systems adopted the Dubray-Howell perforation and are currently using it. Both Trucolor and Cinecolor in making this decision found that they could successfully register from Bell & Howell perforated negatives to Dubray-Howell perforated color prints.

Technicolor, unfortunately, although fully aware of the industry's long struggle for a universal perforation and of the successful use of the Dubray-Howell perforation by other color companies, adopted the Eastman positive perforation without consulting or advising the producing companies of that decision. Perhaps Technicolor did not realize the studio significance of this decision. However, when studio photographic effects departments were notified that after a certain time all Technicolor prints would be supplied with Eastman positive perforations, it became immediately evident that process projectors and perhaps other studio-owned precision equipment would require interchangeable movements in order to handle both Technicolor prints and black-and-white, or prints of any other color system. The cost of duplicating such movements is in itself moderately high, but what is much more important, such a situation materially adds to the danger of confusion and delay in any operation involving process projection photography.

The matter was called to the attention of the Research Council and a meeting involving all those interested, from manufacturers, commercial laboratories and studios, was held. As a result of this meeting, a comprehensive series of tests was laid out by the Research Council in the hope that the industry could be convinced that this was the time to adopt a universal standard perforation and thus for all time avoid any further confusion and expense which must in-

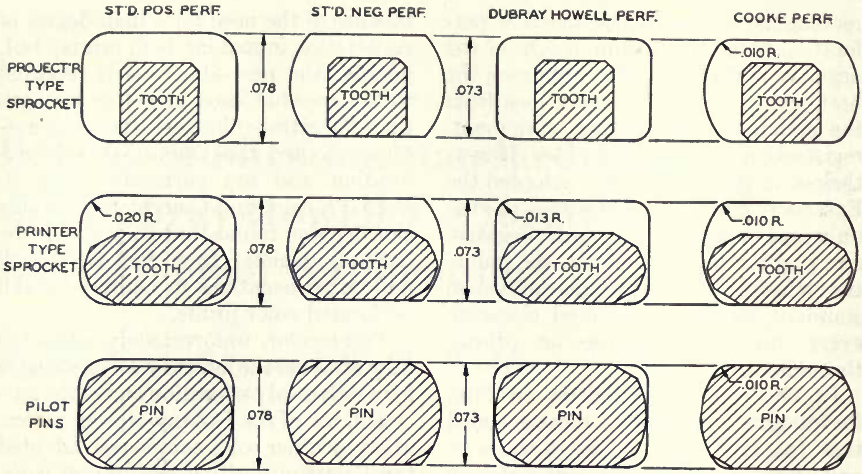

Fig. 1. Drawing showing the fit of various perforations, pilot pins and sprocket teeth.

evitably result from what used to be a double standard and is now a triple standard.

Four perforations were considered: the Bell & Howell, Eastman positive, Dubray-Howell and Cooke (Fig. 1). Experience and history had already eliminated the Bell & Howell and the Eastman positive perforation as candidates. Discussion with experts in printing problems, particularly having to do with the continuous type of printer on which better than 90% of all release prints are made, revealed that the square end of the Dubray-Howell perforation was preferred over the rounded end of the Cooke perforation. It was also the belief of many industry experts that in other problems of registration, the Dubray-Howell perforation was superior to the Cooke. As a result, efforts were confined entirely to the Dubray-Howell perforation.

Generally speaking, there are two problems involved: one is projection life and the other is registration. Each, of course, has a variety of important problems under that general heading. Study of projection life was divided into two parts: accelerated tests and normal release tests. Actually, there is already considerable experience in normal release through the color systems which are using the Dubray-Howell perforation commercially, but it was recognized that these color prints present a different projection-life problem than normal black-and-white prints. Accelerated life tests on black-and-white prints, made by other investigators on carefully aligned projection equipment, have shown approximately 10% greater life with the Eastman positive perforation than that obtained with the Dubray-Howell perforation. It was, however, recognized by the engineers in charge of these tests that normal release conditions might indicate a different answer because theater projectors are not universally as well aligned as these test projectors. Accordingly, the accelerated test was deliberately made in a projector out of alignment and using badly worn sprockets. Figure 2 is a photomicrograph of one of these sprocket teeth. Since it is badly undercut on both sides of the tooth, it has probably been reversed in the machine at some time during its life. This test reel was run approximately 300 times before the

test was stopped. Although the film was not run to destruction, it was evident at this time that in a machine as badly aligned as this one, the film could not run many more times.

Figure 3 shows a photomicrograph of one corner of the Eastman positive perforation at the end of the running, and Fig. 4 shows a similar corner of a Dubray-Howell perforation. In both cases the tooth interfered at the corner of the perforation and caused a serious rupture of the film. Inspection of about 80 ft of each of the two prints involved in the reel led to the conclusion that the Dubray-Howell perforation was standing up a little bit better under this particular test than the Eastman positive perforation. While this is contrary to the projection-life tests previously referred to, it is not an unexpected difference, because the smaller radius of the corner fillet in the Dubray-Howell perforation means that the straight portion of the perforation is longer than is the case in the Eastman positive perforation; thus, corner interference will begin with an Eastman perforation before it begins with a Dubray-Howell perforation.

As this article is being written, the partial release test has not yet been completed, but there is a picture in release in the Los Angeles exchange area in which half of the 1000-ft release is perforated with the Eastman positive hole, and the other half uses the Dubray-Howell perforation. These are so staggered as to fairly cover head reels and tail reels and both projectors in any theater where the print is run. No diffi-

Fig. 2. Photomicrograph of a sprocket tooth of test projector.

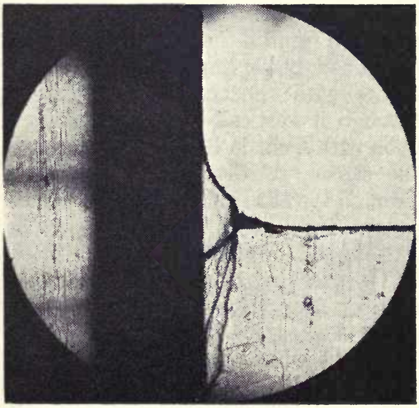

Fig. 3. Photomicrograph of the corner of an Eastman positive perforation.

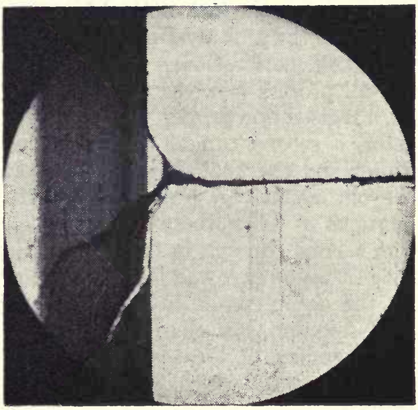

Fig. 4. Photomicrograph of a corner of a Dubray-Howell perforation.

culty is foreseen in this test; in fact, it is expected that it, too, will support the results that have been obtained experimentally and commercially in so many other cases.

The registration tests required a great deal of careful planning and became involved in factors which are not in themselves a part of the test. Since the industry is in the process of changing from nitrate base negatives to safety base negatives, factors which might be influenced by this change in base material could not be neglected. Similarly, the low shrinkage characteristics of the safety base film have made it necessary to manufacture such negatives with a shorter than standard perforation pitch. Thus the perforation pitch had also to be considered in this test.

In projection process photography, stationary foreground objects are commonly photographed together with the rephotographing of a projected picture. This, in the final composite result, provides an extremely critical test of the steadiness of a motion picture, since the eye constantly has the opportunity to observe foreground and background objects where any relative motion is exaggerated. Since this form of photography presents one of the most critical registration problems in the industry, it was chosen as the test method for comparison of the Dubray-Howell and Bell & Howell perforations. Briefly, the over-all process involves the first camera, a registration printer, a process projector, a second camera, a continuous printer and the final theater projector. The outline in Fig. 5 shows the combinations of all of these factors which were carried through in this test. The basic situation involved is quite simple, but the detail results in complications which require very close study for an understanding of the tests themselves and the results which have been obtained.

The program was laid out to cover all practical combinations of pilot pins and perforations for nitrate and safety base, short pitch and standard pitch negatives, in a chain of operations which was as follows: A chart, as shown in Fig. 6, was photographed in the background camera. The film was rewound, the chart shifted slightly and a second exposure was made. This film was developed and printed in a step contact printer, resulting in a process plate as shown in Fig. 7. This process plate was then projected through a process projector onto a translucent screen. Between the process projector and the screen was a latticework covering the full area of the screen. This casts a network of black lines on the screen itself and provides a new reference point. A standard production-type camera photographed this process screen and normal release type prints were made from that negative.

Figure 8 shows a frame of the release print. The parallel white lines and the identifying slates at the top middle and lower right were photographed by the first camera and projected on the process screen. The network of black lines is the shadow of the latticework between the projector and the screen, the broad black line extending in an "L" shape at the lower right corner was created by a gobo [section of dark wallboard often set up to shield camera lens from light] placed in front of the screen. Similarly, the broad black line at the lower left corner with the narrow white stripe through it vertically was created by a gobo with a slit in it located in front of the screen, so that the light coming through the slit from the process screen caused the vertical white line. The slate in the lower center marked "Reel b," was located in front of the screen. In projecting these prints, the salient points looked for were movement between the white lines, which is a function of the background or first camera, movement between the black network lines and the white chart lines, which is a function of the first camera, the

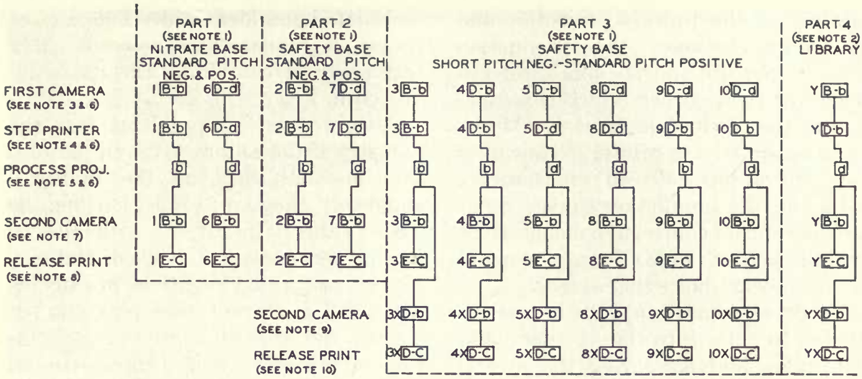

Fig. 5. Outline of perforation registration tests.

Legend:

Numerals – Test number.

Capital Letters – Type of perforation.

Small Letters – Type of registration pin.

B – Bell & Howell (negative) perforation.

D – Dubray-Howell perforation.

E – Eastman (positive) perforation.

b – Bell & Howell registration pin.

d – Dubray-Howell registration pin.

C – Continuous printer.

Note 1: These titles describe the film used in the first (background) camera and process (background) projector only, and do not refer to the second camera negative or the release print.

Note 2: This is the only case where the background negative and positive were of different base material. This background negative was nitrate base, Bell perforated, exposed on a Bell & Howell pin. The background print was Dubray perforated, standard pitch, safety base, made on a step printer having a full fitting Bell & Howell pin, and projected on a background projector having a full fitting Dubray-Howell pin. This would be the procedure followed on existing library material if the Dubray-Howell perforation were adopted as a universal standard.

Note 3: Two full-aperture first (background) cameras were used; the one, in line with regular procedure, had a full fitting Bell & Howell registration pin; the other camera had a full fitting Dubray-Howell registration pin.

Note 4: Two step printers were used; the first had a full fitting Bell & Howell registration pin; the second had a full fitting Dubray-Howell registration pin.

Note 5: Two background process projector movements were used; the first had a full fitting Bell & Howell registration pin; the second a full fitting Dubray-Howell registration pin.

Note 6: The small registration pin (full fitting in height only) was not changed in any of the equipment mentioned in Notes 3, 4 and 5. This is a satisfactory procedure, as the Bell & Howell and the Dubray-Howell perforations are identical in height dimensions.

Note 7: The second (rephotographing) camera had a Bell & Howell registration pin. In this particular series, the negative was Bell & Howell perforated, standard pitch, nitrate base.

Note 8: All these release prints were made on a continuous printer, using an Eastman perforated, standard pitch, safety release positive.

Note 9: This second (rephotographing) camera was identical to the camera described in Note 7, but the negative was Dubray perforated, short pitch, safety base.

Note 10: These release prints were made on the same continuous printer described in Note 8, but using Dubray perforated, standard pitch, safety release positive.

printer, or the process projector, and movement between the production camera aperture and the black gobo in the lower right corner, which is a function of the production camera. Movement of the release printer is shown by the relationship between the sprocket holes and the production camera aperture line and, of course, movement in the final projector is shown by a movement of the sprocket holes themselves.

No attempt has been made in this discussion to enter into the fine details of identifying and measuring the several possible sources of instability, but sufficient information is provided so that by careful study an understanding of the possibilities of analyzing this chart can be obtained. It should perhaps be sufficient to say that by means of these special charts, gobos, latticeworks, special printer and camera apertures and such other devices, the source of any movement which takes place in this chart as it is projected on the screen can be isolated and identified. This was, of course, a fundamental necessity in a test program containing the detail involved in this one.

Several practical problems face the industry if the Dubray-Howell perforation is established as the universal standard; they are: projection life, the use of library negatives with Bell & Howell perforations, the use of Dubray-Howell perforated negatives in cameras with Bell & Howell pilot pins and, of course, the over-all optimum registration obtainable with Dubray-Howell perforations throughout each step in the production of a motion picture.

On the basis of these tests, the following predictions and conclusions are made: There will be no commercial loss in projection life of Dubray-Howell perforated prints as compared to Eastman perforated prints; library negatives with Bell & Howell perforations can be printed to Dubray-Howell perforated process plates with satisfactory

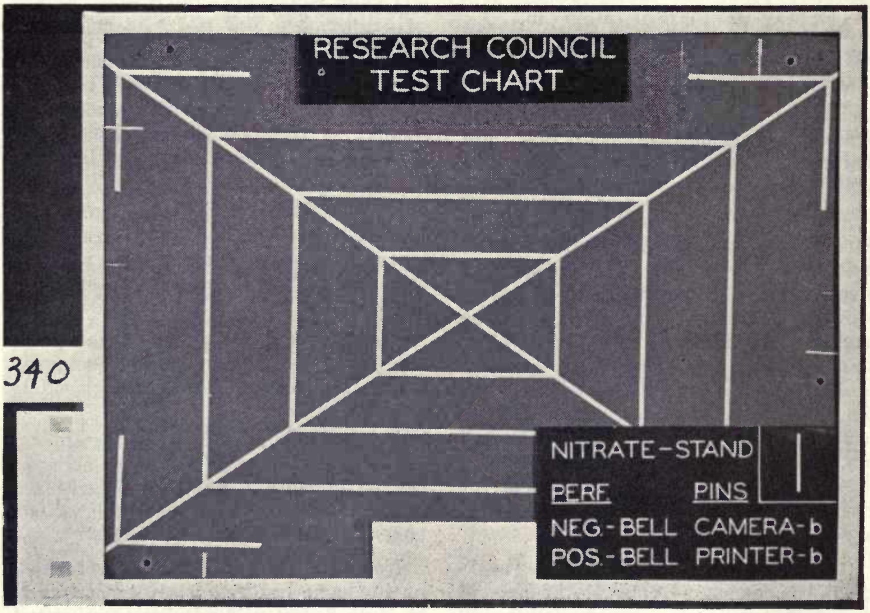

Fig. 6. Original chart — registration tests.

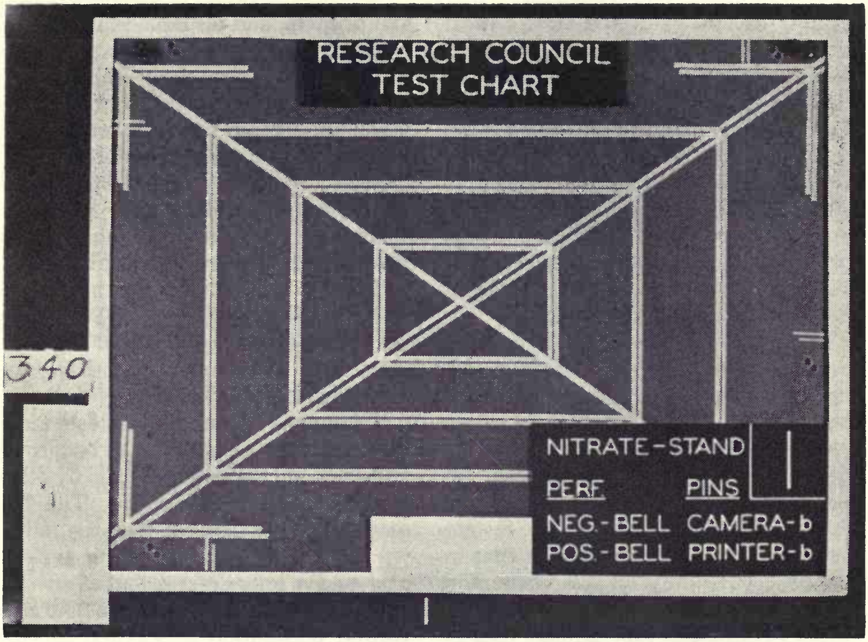

Fig. 7. Process plate — registration tests.

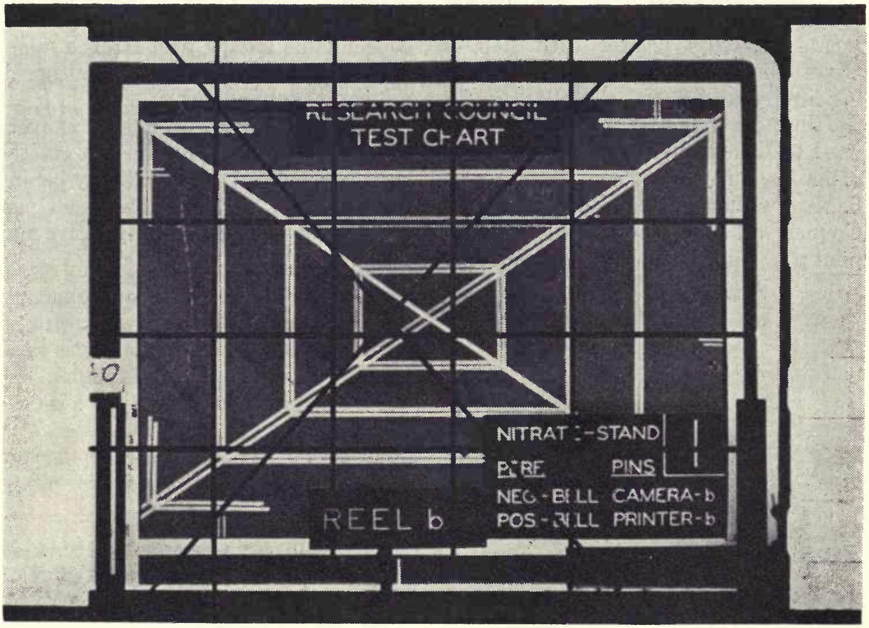

Fig. 8. Release print — registration tests.

results, except where the most critical registration problems are involved; Dubray-Howell perforated negatives can be used in existing cameras without change, and release printers do not need to be changed for printing Dubray-Howell perforated negative or positive films, although some additional improvement can be obtained if the sprockets in such continuous printers are changed to take full advantage of the Dubray-Howell perforation.

The Research Council expects to recommend to its Board of Directors that the Dubray-Howell perforation should be presented to the American Standards Association for adoption as the universal standard perforation for negative and positive motion picture film. Furthermore, it expects to recommend to its member companies that in the use of Dubray-Howell perforated negative and print stocks for normal studio operations, they should change pilot pins in cameras used primarily for process background films, registration printers and process projector movements; a step printer with Bell & Howell pins should be retained for printing library negatives; the pilot pins in the normal production cameras will not need to be changed except as a matter of maintenance; and release printers may be used without change. The Research Council will also recommend changes in pilot pins and sprockets for new cameras and printers, and for replacement parts.

In support of these test results, there is not only the very considerable amount of experimental work done by others throughout the last twenty years, but currently there is considerable commercial experience. Mention has already been made of Trucolor and Cinecolor, both of whom are using Dubray-Howell perforated release prints; but in addition to these it should be noted that Eastman color positive, Du Pont color positive and one experimental negative, as well as its companion positive, are all using Dubray-Howell perforations.

To summarize briefly, the tests made by the Research Council have confirmed and extended the data obtained by other experimenters in this field. The Research Council believes that the industry has an opportunity at this time to achieve the long-desired goal of a single standard perforation. If the Dubray-Howell perforation is adopted as that universal standard, no confusion will be created at any point in the industry, nor will it be necessary to expend any considerable money to make the minor conversions which are desirable although not completely necessary.

It is strongly recommended that every effort be made at this time to get the complete support of the industry behind standardizing the Dubray-Howell perforation for all negative and positive purposes.

Effects of Television on the Motion Picture Theater

By Benjamin Schlanger and William A. Hoffberg

The advent of television has accelerated the need for refinements and improvements in the art of the projected motion picture in theaters. The factors of cinematography, theater location, seating capacity and theater design have to be dealt with in accordance with circumstances which already appear to call for a fresh approach to the problem. It is important to evaluate the ability to adapt existing theaters to the new requirements.

Although home television seems to be acquiring a mass audience, there will always be a motion picture theater and theater television audience consisting of those patrons who wish to see entertainment not available in other mediums, those who wish to avoid advertising intrusions, those desiring a respite from the home environment, those satisfying their gregarious instincts and those who prefer the dramatic impact of the large theater screen cinematography. This audience may be surprising in numbers because it has been estimated that only 10 to 20% of the potential audience ever attended even the most popular picture.

We are now going out of a period in motion picture history in which great leeway existed in both production and exhibition. The margin for error, incompetence and acceptability of questionable quality of production and exhibition is narrowing down with the advent of television. Now, the factor of quality in motion picture theater entertainment will determine the size of its audience. Of course, quality primarily includes story content and performance, but if the motion picture theater cannot deliver the story content and performance in a manner far superior to any of the other entertainment mediums, it will lose the main reason for its existence.

Television has accentuated the necessity for intimacy in the motion picture theater because each home television seat is a "ringside" seat. The television camera is located at a distance and angle from the scene which the director considers most favorable to the home audience. At home, the television viewer has the great advantage of choosing his seating pattern by individual preference. However, the scale of the television screen in the home is limited.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by Benjamin Schlanger and William A. Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53d St., New York 19.

The comparatively bright illumination levels required in home television viewing makes the viewer particularly conscious of this deficiency. The inclusion of furniture and room details in the field of view does much to destroy intimacy.

In contrast with home television, the motion picture theater has a fixed seating pattern. The theater audience seating preferences can readily be seen as they choose their seats at the beginning of the show. The less desirable seats are then reserved for latecomers.

Improving Theaters

The competition of home television can be a healthy stimulus to induce theater owners to improve their physical plant so that the enjoyment of a motion picture in a theater is noticeably superior. The following items deserve careful consideration in this connection:

1. All theater seat locations must be desirable. Unobstructed vision of the screen is mandatory. Ample row spacing and two arm rests for each seat will be necessary.
2. The scale of the theater screen image should increase so that the difference in scale as compared with the home television screen is accentuated and dramatized.
3. Since 1938, we have advocated the elimination of black masking around the motion picture screen and we now have many successful installations of this type in theaters. The majority of television receiver sets have very light colored maskings. A luminous field around the screen, preferably synchronized with the screen lighting intensities, would reduce eyestrain and enhance peripheral cinematographical effects.
4. Some of the fluidity and inventiveness achieved in television production is worth noting. With the larger screen and luminous screen surround, the peripheral areas of the human field of view can be exploited for greater dramatic effect.
5. The effectiveness of distant panoramic views and medium shots on the television receiver is necessarily limited in scale. In contrast, the larger theater screen and the increased use and improvement of wide-angle camera lenses, are great advantages.
6. Development of higher intensity projection equipment, coated lenses, and the reduction of film grain as well as the demands of drive-in projection, have made larger screen projection feasible.
7. Further enhancement of cinematography is produced by the increased subtended angle of the larger screen to the average viewer.
8. Items 2 and 3 of the above recommendations can now help to bring three-dimensional motion pictures into use. With seating depth limited to approximately four times the picture width instead of the greater viewing depths now used, objectionable perspective distortions experienced in stereoscopic viewing will be reduced. The elimination of dark picture surrounds is highly consistent with the realistic effect of stereoscopic viewing.
9. Stereophonic sound in theaters giving positional sound effects in space can hardly be conceivable in home television sound.

The above suggestions for improvement must, of course, be adaptable to existing theaters. In a survey of about 600 U.S. theaters, which was conducted by this Society in 1938, an average screen width of 18 ft 6 in. and an average ratio of maximum viewing distance to picture width of 5.2 was found. An increase of average screen width to 24 ft 0 in. would reduce the ratio of maximum viewing distance to picture width from 5.2 to 4.0 and would increase the screen area by about 67%. This change would be structurally feasible in the majority of existing theaters. It is true that in many of the existing theaters, the use of several of the front rows would be eliminated but the seat loss would be nominal.

With reference to the elimination of black screen masking, the observations and conclusions of L. A. Jones, S. K. Wolf, F. M. Falge, W. D. Riddle, B. O'Brien, C. M. Tuttle, R. G. Williams, H. L. Hogan, M. Luckiesh, and B. Schlanger, since 1920, have indicated the desirability of illumination of screen surroundings. The most desirable contiguous brightness has been found in practice to be the synchronous type which automatically varies with the brightness of the picture. Some of the many examples of this type are the Island Theater, Bermuda; Crown Theater, New Haven; Essoldo Theater, Penge, England; and the Tacna Theater, Lima, Peru. Further developments and refinements for providing a synchronous luminous screen surround have been incorporated into several theaters now under construction, including the Shopping Center Theater in Framingham, Mass., and the Bellmore Theater, Bellmore, L.I.

Locating Theaters

New motion picture theater construction in the U.S. has not been proportional with the increase of population. The growth of television is probably one of the factors which accounts for this. However, new population centers and obsolescence of theaters, both in plant and location, do create a demand for new theaters. Several recent developments have greatly affected the location and seating capacity of new theaters.

Since 1945, new residential planning has tended to be in the form of large-scale, integrated communities very often decentralized. Shopping and night-life centers are then located either within the new communitiesor on the perihpery adjacent to highways. The necessities for parking areas then become a major consideration in theater location. With high land values, it is difficult for new theaters in existing urban night-life centers to provide adequate parking facilities. There has, therefore, been a tendency to locate new theaters within the confines of the new communities or in the shopping centers.

When new theaters are located within the confines of new communities, they have the ease of accessibility of the neighborhood theater. The architectural planning of residential projects very often indicates the use of several smaller theaters, with capacities in the order of 400 to 600 seats, rather than a single large theater. The smaller theaters have fewer building code restrictions and are more economical in per seat cost of construction. Their scale suggests simplicity of exterior treatment and amenities. They do have the virtue of intimacy within the interior of the theater and can achieve to the greatest degree the previous suggestions as to screen size and treatment. All of the seats can approximate the "ringside" seat. Availability of screen product and allocation of runs to groups of smaller theaters is an industry policy question of great importance.

The location of theaters within new large-scale shopping centers has different aspects. Adequate parking facilities are available, the theater plays an important part in building up night activity and there is, generally, considerable transient automobile traffic. This indicates a larger capacity theater. To achieve intimacy in the larger theater is an architectural challenge. Reduction of the interior volume of the auditorium to a minimum helps to create acoustical intimacy. Screen size is, of course, increased in the larger theater and with it, the scale of the screen surround treatment is increased. This enhances the visual intimacy which is the prime consideration. Then, the shaping of walls and ceiling, the avoidance of decoration which gives scale "measuring rods" and the integration of interior lighting must attempt to approach intimacy of space.

New and existing theaters which offer to the public the seating, air condition-

ing, projection and sound transmission comforts, which are now available, and which add to these the increased screen image, the luminous screen field, the increased flexibility and scope of motion picture cinematography, the feelings of intimacy within the auditorium, and stereoscopy of sound and vision, should survive within the forests of home television antennae which have become a feature of the skyline.

References

1. B. Schlanger, "On the relation between the shape of the projected picture, the areas of vision, and the cinematographic technic," *Jour. SMPE*, vol. 24, pp. 402–409, May 1935.
2. B. Schlanger, "Motion picture auditorium lighting," *Jour. SMPE*, vol. 34, pp. 259–264, Mar. 1940.
3. B. Schlanger, "A method of enlarging the visual field of the motion picture," *Jour. SMPE*, vol. 30, pp. 503–509, May 1938.
4. M. Luckiesh and F. K. Moss, "The motion picture screen as a lighting problem," *Jour. SMPE*, vol. 26, pp. 578–591, May 1936.
5. Ben Schlanger, "Auditorium light control through surface treatment," *Better Theaters, Mot. Pic. Herald*, Apr. 2, 1938.
6. Ben Schlanger, "Increasing the effectiveness of motion picture presentation," *Jour. SMPE*, vol. 50, pp. 367–373, Apr. 1948.

Discussion

Pierre Mertz: Some years ago, there was a development in films which seemed to cover something of what Mr. Schlanger had in mind with regard to the wide screen —the Grandeur film. That occurred before I came into this field. Can you tell us, what was the improvement in realism with the Grandeur film as compared with the conventional film?

Mr. Schlanger: There are many factors involved. First, there was a larger physical width of film, and I believe since then the film grain problem has been more or less licked and that a sufficiently large picture can be projected from 35-mm width. The present standard gives a wide enough picture in theaters, and the real problem, which was not licked at the time that Grandeur and other wide, enlarged screens were presented, was the cinematographic problem. It is quite natural. It was a new tool and it never had its chance for the experience or practice that is needed with a new tool. In other words, the cinematographers never became familiar with the new tool or its potentials at that time. Today we are in a spot where we know we need some new method or device, and, should we find it, the cinematographers will learn to use it. As to the realism that can be achieved, there is another problem in addition to that of the size of film and the art of cinematography—that is the taking-lens in the camera. I remember getting in touch with some of the authorities and manufacturers of lenses to try to find out why there were not wider-angle lenses available or used in taking motion pictures, and the significant answer was that there was never any great demand for them. But it was possible to develop them. I do hope that they will develop wider-angle lenses, because that is another tool in the flexibility of cinematography that is necessary.

Frederick J. Kolb, Jr.: Most of the desirable features of theater design that you have discussed seem directly contrary to the requirements of a drive-in theater. Is it possible to reconcile the two?

Mr. Schlanger: Would you be specific as to their being contrary?

Dr. Kolb: I am thinking of the drive-in theater as having a very limited angle of view—more like the home television viewing conditions. Therefore the advantage to be gained by including a larger story element on the screen and by restricting the audience to the most favorable locations seems very difficult—at least, to me—to realize in drive-in design.

Mr. Schlanger: In drive-in theaters, the remote car positions are at least 10 W [W = screen width]. They are placed so because of the physical problem of getting enough attendance with one screen and I have noticed that there have been some developments recently for double screens and even four screens. I guess that is one of the problems to be overcome. From a 10 W location in a drive-in theater, the picture looks like a postage stamp. It is not that it is poorly done. It is an incon-

spicuous speck in the field of view. However, the drive-in theater is a unique experience—to be able to ride out in your car and go and view a picture is still "something different." The audience will tolerate a lot when a thing is unique enough. For example, even home television, good as it is today, falls far short of the quality of a motion picture in a theater. But it is tolerated; it is considered all right because it is unique. You can sit in your slippers, smoke a cigar and watch television without leaving your house. Getting back to your question—can you produce a picture which is just as useful in a drive-in theater as in any other theater? There is an inconsistency in this respect and it can be related also to television viewing. Due to the deficiencies in television viewing there is a tendency, and justifiably so, to use close-ups, because middle and distance shots appear indistinct. For the same reason, middle and distance shots in drive-in theater production should also be avoided. There again, a predominance of close-up shots is a desirable thing, if drive-in theaters are going to be designed with 10 *W* viewing. So, you are correct. A picture which would be photographed carefully for a drive-in would not be good for regular motion picture theaters, but there is always a happy medium. You must be sure that the close-ups are not too close up, and that the distant shots are not too distant. You have to compromise, and I believe that this could be done easily enough so that there would be neither too many close-ups for viewing in the regular theater, nor too few, for the drive-in theater.

WALTER E. DUNN: You have made repeated references to the elimination of black screen masking. Do you have any recommendation for either a substitute or a system of elimination of the mask in an existing thaeter?

MR. SCHLANGER: There are several methods of eliminating black masking. First of all we have to realize that black maskings were originally created for purposes which no longer exist. One was that screen illumination in the early days was comparatively low and the black masking went a long way toward making the illumination appear brighter. I think that television viewing is proving that black masking is no longer necessary. With the exception of the Du Mont sets, practically all the sets have a white or almost-white color masking. The other reason for black masking was to do something about the aberrated or fuzzy edge of the picture as it is when projected without a black masking. That is a practical problem. This aberrated, fuzzy edge can be eliminated in several ways. We have been developing a substitute masking, a luminous masking, which I think will be available very soon. We have also had other solutions in which we would cut the picture, that is, project the picture very carefully into a proscenium which was exactly the size of the picture and let it go at that, or by having a slight flare come right out from the picture. The fuzzy edge would fall on the angular surface, which would not be visible to the audience, and the picture would appear to have a clean-cut edge. Some of the newer maskings that have been developed will do an even better job.

LEONARD SATZ: I'd like to add to that that there are certain things which, in my opinion, can be done right now, short of making major changes. I would say, principally, modernization of lighting would be the first step in the theater auditorium—the elimination of distracting side-wall brackets, which are so common in many of our theaters, and replacement with an operating light which is directed downward and perhaps intentionally directed to the proscenium area. The first step would be, naturally, the enlargement of the screen, and I believe it is a fact that visual acuity is not lost by the reduction in screen brightness as long as the image is increased in size. You mentioned limitation of screen brightness as being one of the problems of the exhibitor today. I think that if he does lose 10% in incident illumination by enlarging his picture with existing projection equipment, the loss will be compensated by the fact that visual acuity is maintained with the larger picture.

MR. SCHLANGER: It may not be exactly compensated, but certainly acuity increases with the size of the image, despite loss in light. I don't have exact figures on that, but I believe you can verify it.

Some Comparative Factors of Picture Resolution in Television and Film Industries

By H. J. Schlafly

This paper reviews and compares the quantitative meaning of the term resolution as commonly used by the television industry and the film industry. The danger of using values of limiting resolution as the sole measure of picture quality is discussed. Conversion equations are developed and tables listing numerically equivalent values of resolution are provided.

The merger of electronics and photography into the corporate function of television recording has resulted in a unique situation. It is a situation which is logical and natural, but which, nevertheless, has caused misunderstandings, delays and even exasperation. The problem is simply one wherein two sciences that have hitherto been comparatively independent of each other suddenly find that they define and describe certain phenomena in terms which are not identical, but which are similar enough to be thoroughly confusing.

The ultimate objective of both television and photography is the faithful reproduction of an original scene. But, while the beginning and end products are the same, the medium and methods are widely different. Thus, it is little wonder that there are few, if any, existing experts who are so thoroughly familiar with the terminology and techniques of both sciences that they can point out in advance the areas of confusion or misunderstanding. This paper will attempt to deal with only one "area of confusion," the meaning of picture resolution as defined by terminology in current use.

A contribution by H. J. Schlafly, Twentieth Century-Fox Film Corp., 444 W. 56th St., New York 19. *Reprinted* from *Proceedings of the I.R.E.* for January 1951.

General

The resolving power of a medium or a device is a measure of the ability of that device to convert, transmit or reproduce details of the original scene. Detail, of course, is a "separately considered particular,"[1] which contributes to or is part of the whole. A device which is capable of handling more or finer detail is said to have the greater resolving power and the resulting picture has more resolution. Lack of picture resolution not only results in the subordination or complete loss of parts of the original, but also in a loss of "edge sharpness" which gives the pic-

ture a "soft" or, more correctly, a diffuse quality. The accepted method of determining resolution is to provide a scale or chart having calibrated points or steps of increasing fineness of detail and to determine the point at which the device under test breaks down in the performance of its function. The human eye itself has a certain resolving capability which is influenced by the portion of the retina being used, the spectral content of the light and the absolute value of the light energy, as well as by the optical characteristics of the lens. Each technical device which precedes the seeing process of the eye has its own resolution characteristic and contributes its part to the degradation of the original scene.

In general, the deterioration contributed by any physical device is evidenced by a gradual reduction in contrast ratio with increasing detail until a point is reached where there is no distinction between two adjacent points which did have some quality of distinction in the original. Whether this contrast ratio is measured in light energy, grains of silver deposit per area, potential difference or whatever, is immaterial. A notable exception to this gradual deterioration of resolution is the "sharp cutoff" voltage amplifier which might maintain constant amplification with increasing frequency (detail) until a certain critical or cutoff point is reached, and thereafter drop sharply toward zero output.

Comparative physical sizes play a large part in determining the point where "signal attenuation" begins to occur. Thus, so-called "aperture size," or the area within which there can be no differentiation, such as a single nerve ending in the eye, the focused scanning spot in a cathode-ray device or the grain size in a photographic emulsion, is a major contributor to the limitation of resolution. But there are many other contributing causes which do not necessarily deal with physical size, such as electrical time constants; aberrations in optical devices; phase shift in amplifiers; spectral sensitivity of emulsions, photocathodes and lenses; and, unfortunately, others.

Today both the photographic and television industries speak of the absolute limit of resolution as a measure of picture quality. Actually the evaluation of quality is so complex that measurement of one of the contributing factors is not adequate to describe the end result. Much work has been done and is being done to determine all of the factors involved.[2,3] In particular, analytical attention is being given to detail contrast ratio, random noise, brightness, and tone reproduction as well as to limiting resolution. The paragraphs which follow deal only with definitions and conversion factors for the resolution terminology in current use and should definitely not be considered as the sole measure of picture quality.

Terms

One is likely to assume that the use of the common term "lines" permits a basis for comparison between photography and television picture resolution. Such is not the case. Each industry has independently arrived at a definition in language best suited to its own measurement technique and, as a result, numerical values which are not apparently related might refer to the same degree of "absolute" resolution in a television picture and in a photograph.

The film industry defines resolution in terms of lines/mm of film surface. Typical test charts are provided by the National Bureau of Standards (shown in Fig. 1) and by the American Standards Association. Such charts usually consist of a series of blocks or squares of parallel black lines separated by clear spaces of the same width. Each block represents a given number of black lines/mm of film surface when the chart is photographically reproduced on the film emulsion. For determining resolu-

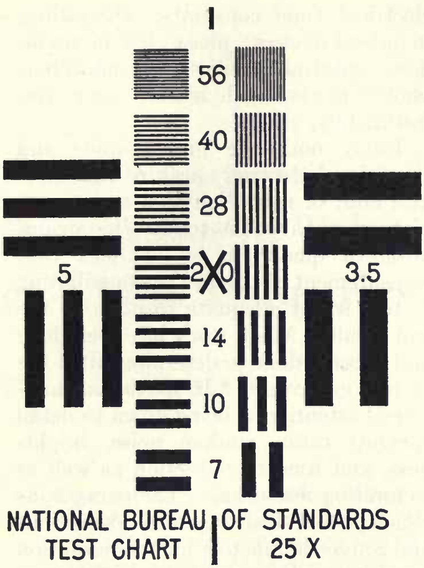

Figure 1.

tion values given in film specification sheets, the contrast ratio between the black lines and the clear spaces on the original chart is held at 30:1. Incidentally, this is about the highest value which can be obtained on a printed chart. Transmission-type charts, used in some resolution measurements, can provide contrast ratios of 100:1 or 1000:1.

The resolving power of a given film emulsion is determined by photographing a test chart using the optimum exposure, processing the film by recommended methods and examining the image under a microscope. The maximum number of black lines/mm just resolved, not lost as an indistinguishable gray mass, is the value used to indicate the resolving power of that particular film. In practice the resolving power values of commercial films vary from about 55 lines/mm for negative film to as high as 150 lines/mm for fine-grain sound recording films.

Of course, the figures given in the above paragraph do not necessarily represent the end product of film resolution as seen on the screen of a motion picture theater. In February, 1946, a portion of the Television Committee of the Society of Motion Picture Engineers made observations of screen resolution of a special test film projected in a group of leading New York theaters. These data were not published because the tests were not sufficiently extensive to permit definite conclusions. In the words of the Committee report: "The influence of many individual factors has not been determined, but it is believed that the results...are broadly representative of present motion picture practice...." The conclusion reached in the same report stated, "In general, it can be concluded from theater projection of the two test films specially prepared for the use of this Committee that projection in first-run theaters shows resolution of 28 lines/mm on 35-mm film where the test object includes pictorial subject matter and 40 lines/mm where the test card alone was photographed."

In the television industry picture resolution is usually measured with the aid of a test pattern such as the RMA Resolution Chart 1946. This chart follows the practice of using horizontal and vertical wedges rather than a series of parallel lines. The pattern is composed of a given number of alternate black and white lines of equal width which continuously converge from the wide to the narrow end of the wedge. Thus, the chart is provided with a continuously variable resolution pattern, numerically calibrated by indexing various points along the wedge. Each black and each white line is counted as an individual line, whereas in the film industry each black line only is counted as an individual line.

The resolution of the television picture is indicated by a value which represents the limiting number of black and white lines identifiable as such, not lost in an indistinguishable gray, in a verti-

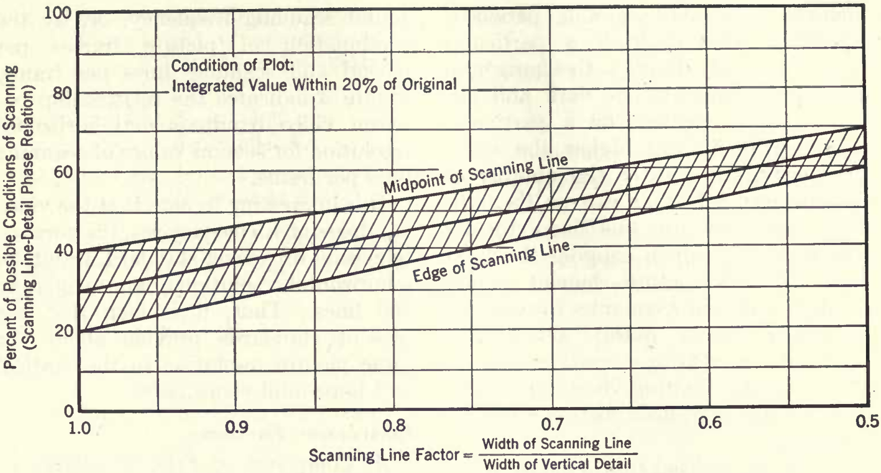

Fig. 2. Integrating effect of scanning line on vertical television resolution.

cal or a horizontal dimension equivalent to the picture height. For the purpose of assigning this value, it is assumed that the resolution of any and every point in the picture is equal to that observed at the wedge. Such an assumption is, of course, not true, but it is a convention which provides a numerical value of resolution accepted throughout the industry. Degradation at the corners of the picture sometimes is identified by the term "corner resolution" and is evaluated by the same process—interpreting the resolution of a wedge located in the corner in terms of the full dimension of picture height.

It is a common error to confuse the number of horizontal scanning lines as set by the television standards with the figure for picture resolution. The television standards in this country specify 525 horizontal scanning lines per picture frame. Only 92% to 95% of these are active scanning lines, the remainder being blanked out during the vertical sweep retrace. But even the remaining 480 some odd lines do not specify the limit of vertical resolution. There is an additional loss in vertical resolution inherent in the television dissecting process which provides a second factor even when there is perfect interlace of the alternate scanning fields. This effect is illustrated by integration of those portions of black and white resolution lines within the width of the scanning line and point by point comparison of the resulting halftone with the original.[4] Figure 2 plots such information for a range of scanning line factors, showing the percentage of possible scanning-line–resolution-line phasing for which the integrated halftone will be within 20% of the original. Choice of a scanning line factor may be a matter of individual preference but a value of 0.75 is commonly accepted and is the value used in the equation derivations included in this paper.

Using these factors, present-day standards, therefore, impose a limitation on vertical resolution of the television picture of approximately 360 lines.

Television picture resolution, by virtue of common usage among electronic personnel, has also come to be identified in terms of bandpass, or maximum pass frequency of the video circuits. Such usage has meaning only when applied to horizontal resolution and then only if a

definite horizontal scanning period is specified. One cycle of a particular video frequency during active horizontal scanning represents one dark and one light picture element on a particular scanning line. The higher the video frequency, the greater the number of picture elements that can be theoretically squeezed into one line. Ideally the one cycle which supplies the light and the dark picture element should contain sufficient harmonics to resemble a square corner pulse; actually, a sinusoidal waveform is considered sufficient for the limiting condition, sacrificing "edge sharpness" between picture elements.

It will be realized that a longer scanning period would permit more cycles of video signal to be included in one scanning line and thus the value of horizontal resolution would be increased. The scanning period is set by the horizontal scanning frequency, or, by the combination of picture frames per second and scanning lines per frame. Figure 3 indicates the relationship between video bandpass and horizontal resolution for several values of scanning lines per frame.

It is interesting to note that the video bandpass of 4.5 megacycles, the nominal television broadcast standard, results in a horizontal resolution of approximately 360 lines. Thus, it is seen that the present standards provide about the same picture resolution in the vertical and horizontal coordinates.

Conversion Factors

A. Conversion of Film Resolution in Lines per Millimeter to Television Resolution in Lines.

$$R_t = 2H_f R_f$$

where R_t = television resolution in lines per picture height

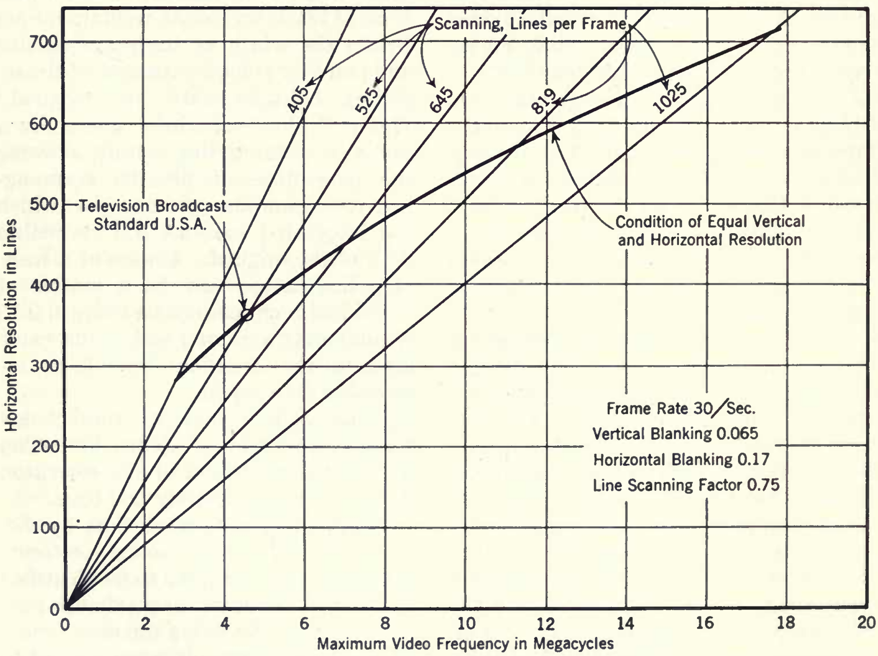

Fig. 3. Television resolution.

R_f = film resolution in lines/mm
H_f = height of standard motion picture projector aperture in millimeters.

For 35-mm film $H_f = 15.25$ mm
$R_t = 30.5\ R_f$

For 16-mm film $H_f = 7.21$ mm
$R_t = 14.42\ R_f$

B. Conversion of Television Scanning Lines per Frame to Lines of Vertical Resolution (Television).

$$R_{tv} = b(aL)$$

where R_{tv} = vertical resolution (television) in lines
a = vertical blanking factor
b = line scanning factor
L = total number of scanning lines per television frame.

Substituting present standards:
a = 0.92 min., 0.95 max., 0.935 average
b = 0.75 (representative)
L = 525 lines
$R_{tv} = 0.701\ L = 0.701 \times 525 = 368$ lines.

C. Conversion of Maximum Video Pass Frequency to Lines of Horizontal Resolution (Television).

$$R_{th} = 2f_{\max}T_h/A$$

where R_{th} = horizontal resolution (television) in lines
$f_{\max}$ = maximum video pass frequency in megacycles
T_h = active time (unblanked) of horizontal sweep in microseconds
$= C\dfrac{1}{L(F_r)}10^6\ \mu\text{sec}$

where C = horizontal blanking factor
F_r = frames per second (television)
A = television aspect ratio.

Substituting present standards:

$f_{\max}$ = 4.5 megacycles
C = 0.82 min., 0.84 max., 0.83 average
F_r = 30 frames/sec
$T_h = 0.83\dfrac{10^6}{525 \times 30} = 52.7\ \mu\text{sec}$
$A = 4/3$.

then $R_{th} = 2 \times 3/4 \times 52.7 \times 4.5$
$= 79 \times 4.5 = 356$ lines

or general formula

$$R_{th} = 79\ f_{\max}.$$

D. General Conversion Formulas for Equal Resolving Power Between Film and Television.

1. Television scanning lines per frame in terms of film resolution (required for equal vertical resolution):

$$L = (2/ab)H_f \times R_f$$
$$= \frac{2}{0.935 \times 0.75}H_f \times R_f$$

$L = 43.5\ R_f$ for 35-mm film
$L = 20.6\ R_f$ for 16-mm film.

2. Maximun video frequency in terms of film resolution (required for equal horizontal resolution) in 525-line, 30-frame television system:

$$f_{\max} = \left(\frac{A}{C} \times L \times F_r \times H_f \times 10^{-6}\right) R_f$$
$$= \left(\frac{4}{3 \times 0.83} \times 525 \times 30 \times 10^{-6} \times H_f\right) R_f$$

$f_{\max} = 0.386\ R_f$ megacycles for 35-mm film
$= 0.182\ R_f$ megacycles for 16-mm film.

3. Maximum video frequency in terms of film resolution (required for equal horizontal resolution in a 30-frame television picture), if the number of scanning lines in that picture has been chosen to give equal vertical resolution:

$$f_{\max} = \left(\frac{A}{CF_r}\left(\frac{2}{ab}H_f\right)H_f \times 10^{-6}\right)R_f^2$$
$$= \left(\frac{2A}{abC}F_r \times H_f^2 \times 10^{-6}\right)R_f^2$$

$f_{\max} = 0.032\ R_f^2$ megacycles for 35-mm film
$= 0.00715\ R_f^2$ megacycles for 16-mm film.

The above equations have been applied to several values of film resolution for both 35-mm and 16-mm sound film and the results have been tabulated in Tables I and II. These tables list

Table I. 35-Mm Sound Film

Numerically Equivalent Values of Resolution		Minimum Television Standards Required for This Resolution		
Film (lines per mm)	Television (lines)	Horizontally* (video freq.)	Vertically & Horizontally (lines/frame)	Vertically & Horizontally (video freq.)
90	2740	35 mc	3900	260 mc
40	1220	15	1700	51
28	850	11	1200	25
17	520	6.5	750	9.3
11	335	4.2	475	3.9

Table II. 16-Mm Sound Film

90	1300	16 mc	1850	58 mc
40	580	7.3	820	11
28	400	5.1	580	5.6
17	250	3.1	350	2.1
11	160	2.0	230	0.9

* Provided the standard of 525 scanning lines per frame is retained.

Note: When transcribing film to television or television to film, degradation factors of each system are cumulative. To minimize over-all degradation the resolution capabilities of one system should substantially exceed that of the other. The magnitude of this "safety factor" is governed by operational techniques.

numerical equivalent values of resolution and the corresponding television standards which would be necessary to realize such a value first, of horizontal resolution (with 525 scanning lines per television frame, 30 frames/sec) and second, of both vertical and horizontal resolution (with 30 frames/sec).

These tables could be interpreted to say that, provided *all other factors affecting picture quality are equal*, a television picture having a limiting resolution of 360 lines (the approximate capabilities of the existing television broadcast standard in the United States) is equivalent to a 35-mm sound motion picture film having a limiting resolution of about 12 lines/mm; or, to a 16-mm sound motion picture film having a resolution of about 25 lines/mm. In actual practice film resolution having a limiting value of 30 to 40 lines/mm is not difficult to achieve but, on the other hand, the reproduced film picture is not able to maintain the contrast ratio that can be realized in a reproduced television picture as detail approaches the television cutoff value. Some workers in the field believe that the "other factors affecting picture quality" mentioned above may eventually be so improved in the television system that existing standards will permit a television picture quality closely approximating that of the present-day 35-mm motion picture film in spite of wide differences in the limiting value of picture resolution.

It must be emphasized again that the tables provide numerically equivalent values of resolution. They do not in themselves permit a comparison of picture quality. They in no way indicate the film resolution that is required when a film is to be reproduced over a television system or when a television picture is to be reproduced on film. It is obvious that when a film is reproduced by a television system, or vice versa, the end result will contain the defects of both. For best results, therefore, both systems should be operated as close as possible to their limit of perfection, or, in some cases, be controlled to compensate for defects or limitations of the other.[5]

Summation

Picture quality and picture resolution are not necessarily synonymous. A figure indicating picture resolution is generally a numerical measure of the limit of detail distinction. Picture quality is a function not only of the limit of detail distinction, but also of the attenuation characteristic which accompanies the reproduction of increasing detail, and numerous other factors of reproduction.

The film industry speaks of resolution as a figure indicating the maximum number of black lines, separated by white spaces of equal width, which can be identified in a dimension equal to one millimeter of film surface.

The television industry speaks of resolution as a figure indicating the

maximum number of alternate black and white lines of equal width, which can be identified in a dimension equal to the picture height.

References

1. Funk & Wagnalls *New College Standard Dictionary*.
2. M. W. Baldwin, Jr., "The subjective sharpness of simulated television images," *Bell Sys. Tech. Jour.*, vol. 19, pp. 563–587, Oct. 1940.
3. O. H. Schade, "Electro-optical characteristics of television systems," *RCA Rev.*, vol. 9, nos. 1–4, pp. 7–34, 246–282, 491–527 and 653–686; Mar., June, Sept. and Dec. 1948.
4. A detailed analysis of the effect of finite scanning apertures can be found in: P. Mertz and F. Gray, "Theory of scanning and its relation to the characteristics of the transmitted signal in telephotography and television," *Bell Sys. Tech. Jour.*, July 1934.
5. C. L. Townsend, "Specifications for motion picture films intended for television transmission," *Jour. SMPTE*, vol. 55, pp. 147–157, Aug. 1950.

Image Tubes and Techniques in Television Film Camera Chains

By R. L. Garman and R. W. Lee

In this country the iconoscope is used almost universally for motion picture film camera chains. In Europe the flying-spot scanner has recently come into extensive use. Other pickup devices, storage and nonstorage, such as the image orthicon, image iconoscope and image dissector tube, have been used experimentally or in a limited commercial way. The characteristics of each of these tubes and their associated equipment are discussed, and certain advantages are evaluated with respect to such factors as signal-to-noise ratio, spurious signals, spectral response and transfer characteristic.

Since the time of the early mechanical schemes of light-spot scanning, many different techniques have been employed for producing television signals from pictures on film. A relatively short while ago, charge-storage tubes were acclaimed as a great step forward and away from the rotating-disc or rotating-drum mechanical scanners. Electronic techniques which are now being advanced as a desirable substitute for charge-storage tubes are exactly analogous to the early mechanical schemes. Historically, one development cycle seems to be complete. It is not only possible, but very probable, that further development will produce significant new advances in the art. A review of film projection methods and equipment now in use here or abroad seems very much worth while at this time.

In the discussion which follows, only those projector mechanisms which use a single film and a single gate are considered. More complex schemes which have been proposed are omitted, not through lack of merit, but because space does not permit their inclusion. Also, the survey of photosensitive image tubes is restricted to those commercial types which are currently available.

Projector Mechanisms and Timing Diagrams

The timing diagram of Fig. 1 indicates the nature of the basic requirements on the projector mechanism. The television vertical sweep and retrace are displayed for reference.

The television field frequency and the projector frame rate are those common to American practice, which is characterized by a conventional 24-frame/sec projector rate and a standard 60 cycle/

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sec vertical sweep frequency. It may be noted that British and continental European television practice is based on a 25-frame/sec sweep standard. Conventional film, recorded at 24 frames/sec, provides very satisfactory results when played back frame for frame at this sweep frequency. The simplicity of frame-for-frame playback is not possible in this country, where the closest sweep rate that can be used for playback is 30 frames/sec. Fortunately, the television and motion picture frame frequencies are commensurable, with the motion picture frame time of 1/24 sec corresponding exactly to that of two and one-half television fields.

The usual method employed to make up for the difference in frame rates is that of scanning one film frame twice, the next three times, the next one twice, etc. Pulldown timing diagrams which accomplish this "2-3-2" method of scanning are illustrated in the last three lines of the timing diagram. The shaded areas correspond to intervals of time during which the film is in motion.

Exposure of the pickup device to light from the film entails three tasks. The first is the transition from one motion picture frame to the next. The second is illumination of the field, which must not take place while the film is in motion. The third is a raster scanning process, which may be accomplished by any one of several different methods. Some of these methods require that scanning be completed during the illumination of the field; others permit illumination of the field during a part of the scanning interval; still others do not permit illumination during any part of the scanning interval. Figures 2 to 4 provide a more detailed breakdown of the basic timing diagram with regard to these differences.

Figure 2 shows timing diagrams for film pickup systems in which the field is illuminated during the television sweep retrace time. Again, the vertical sweep and the vertical retrace period are shown for reference purposes. Illumination during the television sweep retrace time can be used with any storage-type

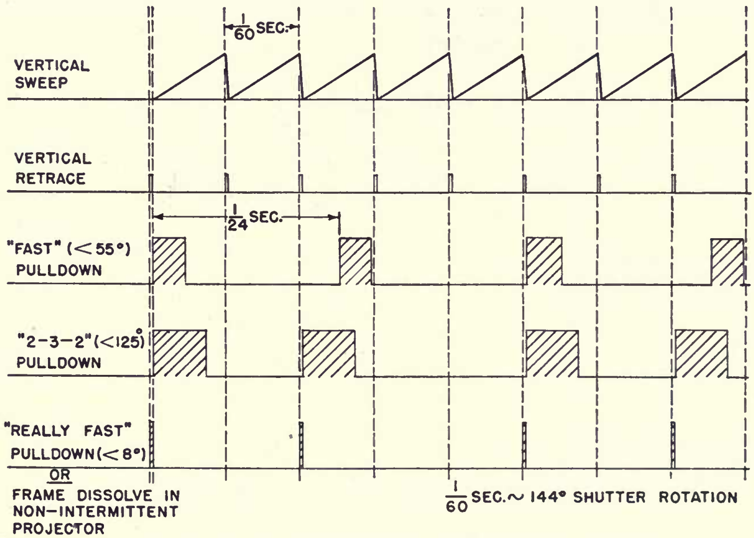

Fig. 1. Basic timing diagram for 24-cycle television projector mechanisms.

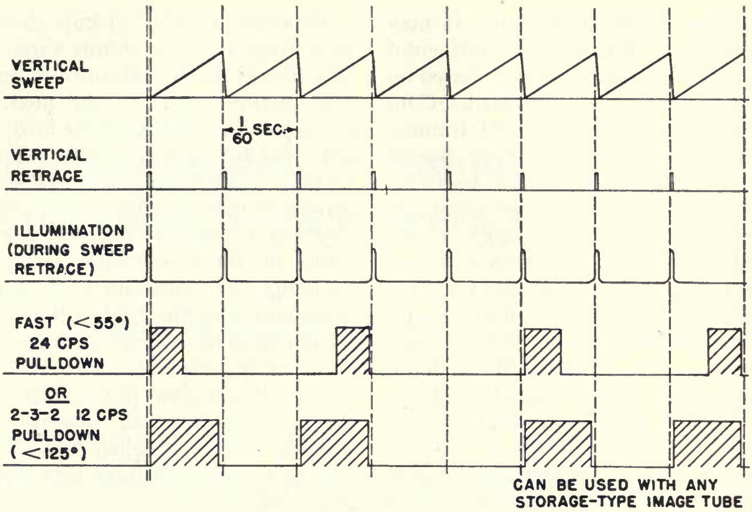

Fig. 2. Film pickup timing diagram; illumination during television sweep retrace.

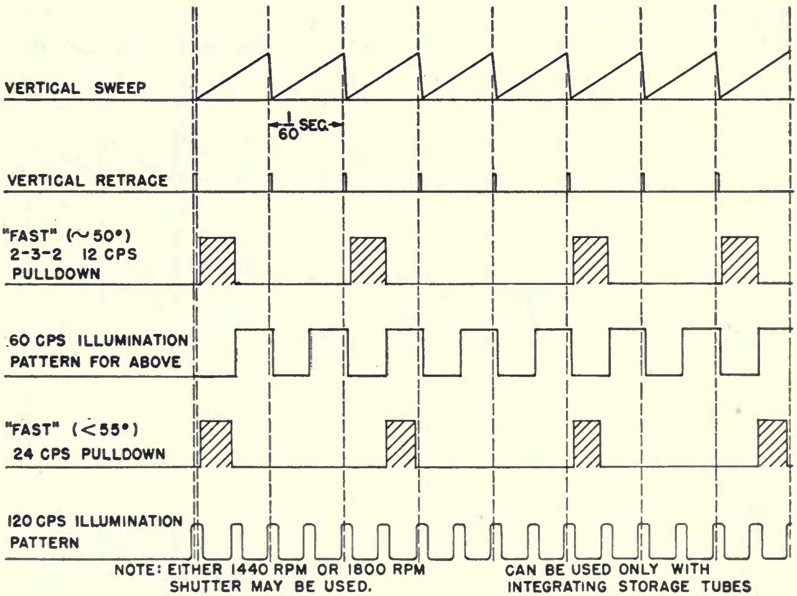

Fig. 3. Film pickup timing diagram; illumination and pulldown during television sweep.

image tube such as the iconoscope, the orthicon, the image iconoscope and the image orthicon. The relationships illustrated are typical of the mechanisms now in use in iconoscope film camera chains in this country. Two types of pulldown timing are in use, the standard 24-cycle/sec "fast" pulldown, and the "2-3-2" mechanism with a basic repetitive pattern at 12 cycles/sec, in which nearly the full television field period is available for film motion.

Figure 3 shows timing diagrams for film pickup systems in which both illumination and pulldown of film may occur during the television sweep time. This method can be used only with a storage tube which integrates linearly the light falling upon the photocathode. The only example of such a tube at present is the image orthicon, which may be used quite successfully for this application. Of course, the film may not be illuminated while in motion, or "travel ghost" will result, as in any intermittent projector without a shutter. The two bottom lines illustrate the timing for one very simple scheme, which may be used with projectors which have a satisfactorily fast pulldown (60° or less). The 120-cycle/sec illumination pattern for this scheme is generated very simply by a regular 24-cycle/sec shutter with five equally spaced slots. Unfortunately, there are extraneous photoelectric effects in the image orthicon which limit the minimum exposure time for this kind of operation. These effects are often visible as a streak across the picture, called an "application bar." The visibility of this bar is more or less proportional to the peak illumination. It is therefore advisable to increase the duty cycle of the projector. There is no strict limit, but generally the performance is acceptable if the shutter open angle is greater than 30°. A satisfactory solution is the use of a rather fast "2-3-2" pulldown mechanism with a 60-cycle/sec illumination pattern obtained from a 12-, 30- or 60-cycle/sec shutter. Inspection of the diagram will show that if the pulldown time is approximately 50° in the "2-3-2" mechanism, exposures of 70° to 80° of shutter rotation can be obtained.

Figure 4 shows timing diagrams for film camera chains in which pulldown

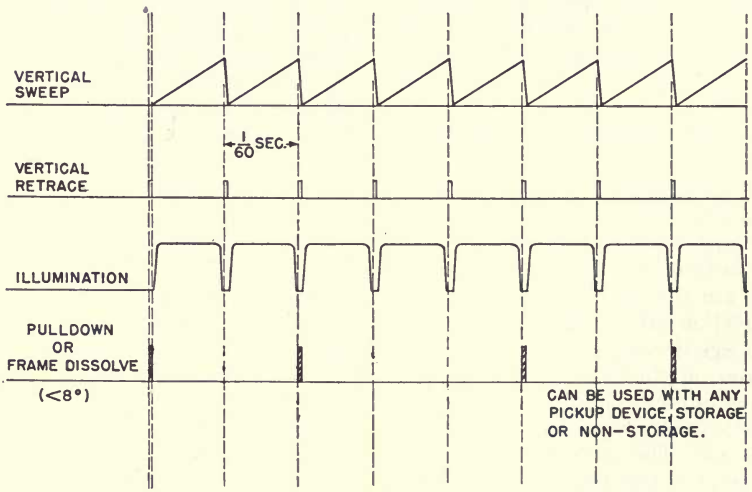

Fig. 4. Film pickup timing diagram; pulldown during television sweep retrace.

occurs during the television sweep retrace time. This mode of operation can be used with any photosensitive pickup device, storage or nonstorage. The illumination must properly be interrupted every 1/60 sec in order to provide equal exposures for each television field scan. If a nonintermittent projector with lap dissolve from one frame to the next is used, continuous illumination is possible. It may well be that, even in the case of the intermittent projector, film travel might be so fast that "travel ghost" would not result from illumination during the retrace time. This possibility may have more than merely academic interest. Ten years ago most engineers were convinced that an intermittent projector with pulldown during the retrace time was not only impossible, but fantastic and ridiculous. This is not the case today. Mechanical intermittent mechanisms which are simple extrapolations of conventional design are now available, and will pull down film in approximately 15° of shutter rotation. Audible noise problems are often acute with these mechanisms. Completely new approaches to the problem now give promise of providing pulldown in less than the minimum vertical retrace standard set by the Federal Communications Commission!

Tube Characteristics

The film projector and the image-sensitive tube are the two elements which distinguish film operations from live studio techniques. In general, the tube types used for film pickup are the same as those developed for live pickup. They are the photomultiplier (used in conjunction with a flying-spot scanner), the image dissector (preferably with an electron multiplier), and the several storage tubes including the iconoscopes, image iconoscopes, orthicons and image orthicons. The parameters which are important in the selection of a tube are signal-to-noise ratio, transfer characteristic, freedom from spurious signals, spectral response and sensitivity. Resolution capability is equally important but will be disregarded in this discussion because of the lack of good data on which to base conclusions.

It is extremely important to recognize that the signal-to-noise ratio and the shape of the transfer characteristic cannot be considered independently in arriving at a real evaluation of obtainable picture quality. The signal-to-noise ratio, measured as the ratio of peak signal to rms noise, is very much affected by the nature of the transfer characteristic of the over-all system, as well as by the noise distribution over the range of light flux utilized. Schade[1] has provided an excellent discussion of the relations between these parameters.

In commercial motion picture practice, an over-all gamma from scene to screen of approximately 1.6 or 1.7 is considered desirable from the audience point of view. It seems likely that the same objective also applies to television practice. In this case, however, the transfer characteristic of the kinescope, direct view or projection, is a power law with an exponent which probably falls in the range 2.0 to 2.8. Ideally, the transfer characteristic from scene illumination to kinescope-grid driving signal should, in turn, be a power law with an exponent probably not exceeding 0.75. In order to compare camera-tube transfer characteristics, it will be necessary to assume that the line amplifiers are linear. On this basis, the present studio practice of using a tube with a linear characteristic, such as the image orthicon, results in raising the effective gamma above the desired objective, even in the case of live pickup where there is no modification of transfer characteristic due to film.

Ordinary motion picture film can be assumed to have been processed to the over-all gamma figure mentioned above. When an iconoscope is used with such film at the illumination levels which are now common in film camera chains, the

result is an approximately linear transfer characteristic to the grid of the kinescope. In this situation, some transfer characteristic correction is probably desirable. When a tube with a linear characteristic is used in combination with the same type of film, the effective transfer characteristic to the grid of the kinescope has a power law exponent of about 1.6. The over-all transfer characteristic to the screen of the kinescope then has the extremely high power law exponent of 3.5 to 4.5. Hence, the use of some form of gamma correction is apparently mandatory when linear devices are used with normally processed film.

As an alternative, film which has been specially processed for use with linear image pickup devices may be considered. However, film processing to an effective gamma of 1.0 is probably the minimum feasible. Such film would give, again, an approximately linear characteristic to the grid of the kinescope and would result in about the same effective over-all gamma as in the case of present studio cameras on live pickup. Such special processing is probably feasible for very large television stations, or for network operations, where the capital available and the magnitude of the operation may enable complete specification and control of all steps in film production. However, as a general approach to the problem of film camera chain design, it cannot be assumed that specially processed film will always be available. Any such design will therefore have to include provision for gamma correction, and again must consider the effect of gamma correction on the system noise level.

In any image tube, there is a noise level set by the fundamental photocurrent associated with the first stage of the process. The noise current, I_{np}, for a given photocurrent, I_p, in a bandwidth, Δf, is given by:

$$I_{np} = \sqrt{2eI_p\Delta f} \qquad (1)$$

where e is the electronic charge $= 1.59 \times 10^{-19}$ coulomb.

For a 4.25-mc bandwidth,

$$I_{np} = 1.16 \times 10^{-6} \sqrt{I_p} \text{ amp.} \qquad (2)$$

Figure 5* illustrates this noise characteristic, which is typical of an ideal pickup device and is approached by the photomultiplier. In the case of storage tubes, the noise level associated with other stages—scanning beams, amplifier input circuits and the like—masks the fundamental noise level almost completely. This case will be discussed in more detail in connection with storage-type pickup tubes.

Storage-Type Pickup Tubes

Since the iconoscope,[3] the orthicon,[4] the image iconoscope[5] and the image orthicon[6,7] have been adequately described elsewhere in the literature, their construction and general mode of operation need not be reviewed here. We may proceed directly to a consideration of those characteristics which are particularly important for the film chain problem.

Table I contains data from a number of sources, both published[7,8] and unpublished, on camera tubes available at present. The Aeriscope and Photicon entries are based on manufacturers' information which has been supplied to the authors. Some obsolete tube types are included for comparison purposes. It may be noted that a very wide range of characteristics is tabulated.

The smallest of the tubes is the Aeriscope, an image iconoscope manufactured by Radio Industrie, in France, having a photosensitive area of exactly the same size as the 35-mm film frame. The Photicon, which is manufactured by Pye, Ltd., of Cambridge, England, is also quite small, having an area less than one square inch. On the other hand, the mosaic area of the

* Similar to curves which may be found in Ref. 2.

Table I. Television Camera Tube Data.

Tube Type	Photosensitive Surface					Highlight Illumination (max. ft-c)	Total Lumens (max.)	Signal-to-noise Ratio*
	Height (in.)	Width (in.)	Area (sq ft)	Sensitivity μa/lm	Spectral Response			
1850A (iconoscope)	3.56	4.75	0.117	7	Approx. Panchromatic	10	1.17	65
1848 (iconoscope)	2.25	3.0	0.047	7	Approx. Panchromatic	10	0.3	35
1840 (orthicon)	1.75	2.31	0.028	10	Approx. Panchromatic	4	0.11	130
Aeriscope (image iconoscope)	0.63	0.84	0.0037	50	Eye Curve	1.6	0.006	"Very Good"
Photicon (image iconoscope)	0.81	1.08	0.0063	60	Eye Curve	4	0.025	65
Flashed Photicon (image iconoscope)	0.81	1.08	0.0063	60	Eye Curve	1.6	0.01	65
5655 (image orthicon)	0.96	1.28	0.0085	6	Blue Peak	0.3	0.0025	70
2P23 (image orthicon)	0.96	1.28	0.0085	20	High Red	0.07	0.0006	35
5820 (image orthicon)	0.96	1.28	0.0085	40	Eye Curve	0.012	0.0001	35
5826 (image orthicon)	0.96	1.28	0.0085	40	Eye Curve	0.05	0.00043	70

* Ratio of peak signal to rms noise.

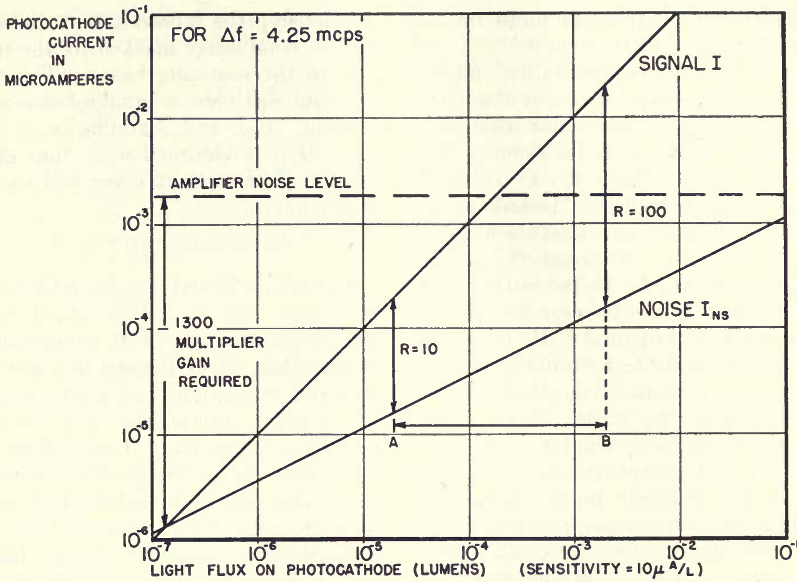

Fig. 5. Noise characteristics for an ideal pickup tube. (From *RCA Review*[2])

1850A, the iconoscope most commonly used at present in film camera chains, is approximately 17 sq in.

The sensitivities of the photo surfaces vary by a factor of approximately ten, the highest figures being obtained in the newest tubes, namely, the 5820 and 5826 image orthicons and the European image iconoscopes. These same tubes also offer an advantage in that the spectral sensitivity curve of the photo surface very closely approximates the eye sensitivity curve, and hence enables very satisfactory operation with white light and color film.

Tube sensitivity is normally specified in terms of the highlight illumination required on the photocathode. This form of specification is not very satisfactory for the television camera designer. The sensitivity of any photosensitive image device is more conveniently measured in terms of total light flux required to give a picture with a specified signal-to-noise ratio, from a definite angular field of view, and with a specified depth of field.[9] Tube handbooks do not, of course, furnish information in this fashion, nor is there much indication of the signal-to-noise ratio attainable. In the case of pickup from film, depth of field is not an important criterion, but a knowledge of the total luminous flux required on the photo surface (independent of the picture size) is pertinent to any projector design. The luminous flux required for each of these tube types is therefore tabulated as the product of the known area of the photosensitive surface and the nominal maximum highlight illumination required. Approximate signal-to-noise ratios, in terms of peak-to-peak signal relative to rms noise voltage for a 4.25-mc bandwidth are also tabulated.

Maximum luminous flux and signal-to-noise ratio figures are illusory in one sense. For example, there is no strict limit on the illumination in the case of the iconoscope. Present practice, as a matter of fact, provides a highlight illumination of 40 to 75 ft-c on the mosaic of the 1850A in most film camera chains. On the other hand, the image

orthicon illumination is more or less limited to the values given.[8]

One entry in this table, labeled "Flashed Photicon" for want of a better term, refers to a particular method of operation of the Pye Photicon in film chains, rather than to a distinctly different type of tube. Details of the method are to be published elsewhere in the near future. However, the general features are known to the authors and are outlined herein by permission of R. Theile of Pye, Ltd., and F. H. Townsend of Cathodeon, Ltd., both in Cambridge, England, to whom acknowledgment for development is made. The timing diagram is basically similar to the third line of Fig. 2, except that flash illumination as well as image illumination occurs during the vertical sweep retrace time. The flash illumination is provided by an auxiliary lamp which floods the photocathode with light during the initial portion of the retrace interval. The resulting photoelectrons provide a uniformly distributed electron shower over the entire surface of the mosaic. Simultaneously, the collector electrode is pulsed negative so that secondary emission is not collected from the mosaic, which then becomes negative relative to the normal collector voltage. The collector returns to normal potential immediately following the light flash, and hence is appreciably positive with respect to the mosaic during image illumination and subsequent beam scanning. With a positive collector, sensitivity is increased and shading problems due to secondary electron redistribution are less acute. It is recognized that this kind of operation is possible only with intermittent exposure of the camera tube, as is the case in most film camera chains.

Noise Considerations in Storage-Type Pickup Tubes

The image orthicon represents the nearest approach to an ideal storage-type pickup tube. As was pointed out previously, the photocurrent noise is almost completely masked by the noise due to the scanning beam. The relationship between scanning-beam-noise current, (I_{nb}), and scanning-beam current, (I_b), is identical with that given for the photocurrent noise and can be written as:

$$I_{nb} = 1.19 \times 10^{-6} \sqrt{I_b} \qquad (3)$$

In the case of an ideal image orthicon, the beam current is 100% modulated. The beam-current noise is a maximum in the black, where the return beam current is a maximum, and a minimum in the whites, where the photocurrent noise is a maximum. This results in a total noise characteristic which is virtually independent of illumination level, and in noise fluctuations which are approximately the same in the blacks and whites. Practically speaking, the image orthicon falls short of this performance because the efficiency of beam modulation is not greater than about 25% or 30%. A very large part of the noise output from the tube is therefore due to the unmodulated beam noise. These relationships are illustrated in Fig. 6,* in which the inherent noise level for an ideal pickup device, the noise level for an ideal image orthicon, and the total noise actually obtained from an image orthicon are all plotted as a function of light flux on the photocathode. It will be noted that the signal current and the inherent noise current are double the values shown in the previous figure, to account for the secondary emission multiplication of approximately 2, which occurs at the target.

In the case of iconoscopes, orthicons and image iconoscopes which do not contain signal multipliers, the noise level is set by the associated amplifier noise level. The equivalent input noise, I_{nt}, to an amplifier with a bandwidth, Δf, and a response characteristic which is

* Similar to curves which may be found in Ref. 2.

flat and independent of frequency over that bandwidth is given by[10]:

$$I_{nt} = 2\sqrt{\frac{kT}{R}\Delta f\left(1 + \frac{R_t R(\omega C)^2}{3}\right)} \quad (4)$$

where: k = Boltzmann's Constant
T = absolute temperature
R = input resistance
R_t = equivalent input resistance due to shot noise in the first amplifier
C = shunt capacity in the input circuit.

This amounts to approximately 2.6×10^{-9} amp for a flat 4.25-mc bandwidth.

It is usually possible to increase signal-to-noise ratio by using a fairly large load resistance. However, because of the associated capacity of the tube and input circuit, frequency compensation is required. It is necessary to peak the amplifier response characteristic to give a response which is proportional to frequency over the bandwidth. The equivalent input noise for a peaked-channel amplifier, (I'_{nt}), has been given by Schade[1] as:

$$I'_{nt} = 3.7 \times 10^{-19}(\Delta f)^{3/2} \quad (5)$$

which for a peaked 4.25-mc channel is approximately 3.4×10^{-9} amp. However, although the measured noise current for this peaked channel is numerically greater than that given for a flat-channel amplifier, the effect on the eye is actually less. This has been noted by Schade,[11] who has produced experimental curves for the detail response characteristic of the human eye. He has shown that, because of the fine grain of the fluctuations associated with a peaked-channel amplifier, the effective noise current for a peaked channel is approximately one-third of the calculated noise current for a flat 4.25-mc channel. The effective noise level in such a channel is therefore reduced by the eye characteristic to approximately 1.1×10^{-9} amp.

Table II presents data on the transfer characteristic and the total luminous flux required for an effective signal-to-noise ratio of 35, for several of the tubes listed in Table I. The total luminous flux at maximum rating is listed for reference. On this basis, the iconoscopes and image iconoscopes offer a very much larger effective signal-to-noise ratio than is obtainable with either of the image orthicons, which have a much lower storage capacity and a flat-channel noise characteristic.

Summary of Storage-Type Pickup Tube Characteristics

The iconoscope can give a very good signal-to-noise ratio when used in a system having the proper transfer characteristic, but it presents difficulties with shading and bias lights, and does not have as good a spectral-response characteristic as might be desired. The image iconoscope is more sensitive, has fewer difficulties with shading, does not require edge or bias lighting, can give just as good a signal-to-noise ratio, and offers a very good spectral-response

Table II. Transfer Characteristic and Effective Sensitivity of Television Camera Tubes.

Tube Type	Power Law Exponent of Transfer Characteristic	Total Lumens at Max. Rating	Total Lumens for Effective Signal-to-Noise Ratio of 35
1850A	0.7	1.17	0.041
1848	0.7	0.3	0.03
1840	1.0 (linear)	0.11	0.0098
Photicon	0.7	0.025	0.002
Flashed Photicon	0.7	0.01	0.001
5820	1.0 (linear)	0.0001	0.0001
5826	1.0 (linear)	0.00043	0.00012

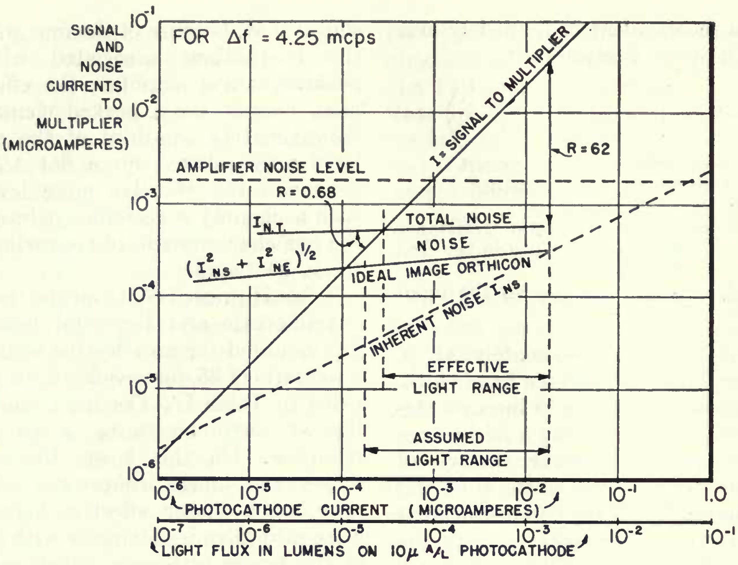

Fig. 6. Noise characteristics of image orthicons and iconoscopes. (From *RCA Review*[2])

curve. The image orthicon is extremely sensitive, requires no shading adjustments by the operator, and in the newer types has a good spectral-response curve; however, its signal-to-noise ratio is not very good when the transfer characteristic required for pickup from film is considered. In terms of picture quality obtainable with storage-type camera tubes, the image iconoscope seems to rate first, the iconoscope second and the image orthicon third. However, the image orthicon must not be discounted where low operating cost, rather than attainment of the very highest picture quality, is of prime importance. Ease of operation, and the relatively simple nature of the associated projection equipment are useful properties for low-cost operation. It is quite feasible to consider a projector used on the studio floor with an ordinary studio image orthicon camera which is dollied up to the projector for film commercials and programs. There are, in fact, many kinds of film operations for which the image orthicon camera will give perfectly acceptable picture quality, at low operating cost.

Nonstorage-Type Pickup Tubes

The earliest mechanical schemes of light-spot scanning, as applied to film pickup, utilized a rotating disc or drum as the source of the light spot and a photocell as the sensing, or transducing, element. The modern flying-spot scanner, using a special cathode-ray tube as the source of the light spot, and substituting a photomultiplier for the diode photocell, is now widely recognized as a device which can provide very high quality signals from film. The multiplier-type image dissector tube is also familiar to television engineers, and can produce excellent television pictures, but to date has received less publicity.

By their nature, these nonstorage pickup devices require continuous illumination of the photosensitive surface during the scanning of the picture. Hence, their use is confined either to

continuous-motion projectors, or to those intermittent projectors in which film pulldown is completed during vertical retrace of the television scan. Unfortunately, neither projector has as yet been successfully applied to pickup from motion picture film in this country.

The necessity of scanning in 2-3-2 sequence, dictated by the difference between television and motion picture frame rates in this country, very seriously complicates the problems of the continuous-motion projector. In England and Europe, where frame-for-frame playback is ordinarily used, the results obtained with a continuous-motion projector and the flying-spot-scanner technique are startlingly good.

Where frame-for-frame playback is possible, the flying-spot-scanner technique applied to pickup from continuously moving film offers some advantages over other methods of pickup. Adjustment of the centering, amplitude and linearity of the raster on the scanner tube allows compensation of certain types of imperfection in film motion. Experimentally, it has been found that the film velocity can be made sufficiently uniform to maintain good interlace and vertical resolution. Very high quality television pictures are obtained from film in this manner in equipment manufactured by the Cinema Television Co., and Electrical and Musical Industries, Ltd., in Great Britain, and by Radio-Industrie in Paris.

The photomultiplier in this application constitutes a nearly ideal pickup device with a noise characteristic similar to that shown in Fig. 5. The highlight flux required for a very high signal-to-noise ratio is about 10^{-3} lm, which is not difficult to obtain from a high-voltage scanning tube especially designed for the purpose.

The scanning tube presents more serious problems, such as the problem of phosphor "grain." Grain results in signal fluctuations which, on close inspection, are seen to be nearly stationary on the raster. Experimental scanning tubes have been built which are relatively free of this defect, but such tubes are not as yet commercially available. Another problem is created by the phosphor-decay time of current tubes. Light output from the phosphor should decay to a low value in a fraction of a microsecond; otherwise light is collected from points along a line behind the flying spot, instead of from the spot alone, and streaking and loss of resolution result. Although it is possible to compensate for slow phosphor decay by proper shaping of the frequency response curve of the amplifiers, the results are not always optimum. Still another problem is due to phosphor color. The light output should be essentially white to enable faithful reproduction of tonal values from color film. To date, the only phosphors found useful for flying-spot-scanner tubes have suffered the defect that the luminous spot is colored green, blue or violet.

The principle of the image dissector tube is illustrated in Fig. 7. A steady and continuously illuminated picture is projected on the photocathode. By conventional television deflection techniques, the photoelectrons emitted from the photocathode are scanned across the stationary rear aperture and amplified by a more or less conventional electron multiplier. The projector may use either continuous film motion or rapid intermittent pulldown. The image dissector tube has the distinct advantage that there is no difficulty in rendition of color film, since a standard projector light source (tungsten or carbon) may be used. For the same reason, it is not difficult to obtain the light flux required (which is greater than that needed for the flying-spot scanner by a ratio equal to the number of picture elements scanned).

A comparison of flying-spot-scanner and image-dissector techniques is difficult because a consistent analysis must

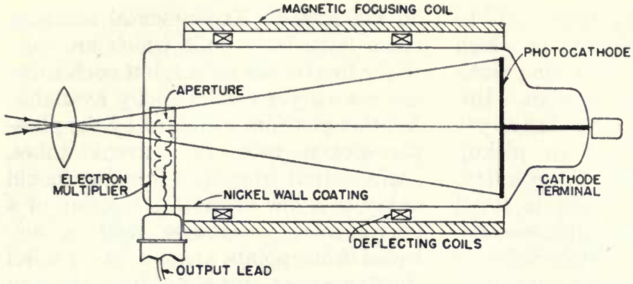

Fig. 7. Principle of the image dissector.

assume projectors developed beyond the point where they stand today. As a personal opinion, the authors submit that the continuous-motion projector will not be the solution; previous attempts do not seem to have yielded a steady enough picture for the dissector tube, and in the case of the flying-spot scanner the problem of conversion from 24 to 30 frames/sec seems to be an insurmountable obstacle. No intermittent projector capable of pulling film into register during the television field retrace time is now available. However, in view of the many development groups at work on the problem, a satisfactory solution seems inevitable. Once such a projector is available, both flying-spot-scanner and image-dissector techniques will offer very interesting possibilities for generating high-quality television pictures from film. Both techniques promise ideal noise characteristic, complete freedom from shading problems, and relatively high sensitivity. At the present time, with projector mechanisms which are available, storage-type pickup tubes offer the only feasible solution.

References

1. O. H. Schade, "Electro-optical characteristics of camera systems" (Part III of a series on electro-optical characteristics of television systems), *RCA Review*, vol. 9, no. 3, pp. 490–530, Sept. 1948.
2. P. K. Weimer, "The image isocon," *RCA Review*, vol. 10, no. 3, pp. 366–386, Sept. 1949.
3. V. K. Zworykin, G. A. Morton and L. E. Flory, "Theory and performance of the iconoscope," *Proc. I.R.E.*, vol. 25, pp. 1071–1092, Aug. 1937.
4. A. Rose and H. A. Iams, "The orthicon," *RCA Review*, vol. 4, no. 2, pp. 189–199, Oct. 1939.
5. H. Iams, G. A. Morton and V. K. Zworykin, "The image iconoscope," *Proc. I.R.E.*, vol. 27, pp. 541–547, Sept. 1939.
6. A. Rose, P. K. Weimer and H. B. Law, "The image orthicon, a sensitive television pickup tube," *Proc. I.R.E.*, vol. 34, pp. 424–432, July 1946.
7. R. B. Janes, R. E. Johnson and R. S. Moore, "Development and performance of television camera tubes," *RCA Review*, vol. 10, no. 2, pp. 191–223, June 1949.
8. *RCA Tube Handbook.*
9. A. Rose, "A unified approach to the performance of photographic film, television pickup tubes and the human eye," *Jour. SMPE*, vol. 47, p. 273, Oct. 1946.
10. H. B. DeVore and H. Iams, "Some factors affecting the choice of lenses for television cameras," *Proc. I.R.E.*, vol. 28, pp. 369–374, Aug. 1940.
11. O. H. Schade, "Characteristics of vision and visual systems" (Part I of a series on electro-optical characteristics of television systems), *RCA Review*, vol. 9, no. 1, pp. 13–37, Mar. 1948.

Characteristics of All-Glass Television Picture Bulbs

By John L. Sheldon

Discussed are methods of manufacturing glass television bulbs, together with engineering data on mechanical, dimensional, optical and electrical characteristics of bulbs and glass. Current trends are given for size, shape and deflection angle.

As an engineering material, glass has an extraordinary versatility and range of useful properties. The important uses in motion pictures and television are too numerous to recite here, except to say that without glass it is difficult to see how the two industries could exist. In the case of television bulbs the properties of glass that are of particular importance are optical clarity, electrical characteristics and high-vacuum properties.

Although picture-tube bulbs may be made of a combination of glass and metal, this paper will deal only with the all-glass type, which predominate in the industry today. Glass is basically a very cheap material and thus is a desirable one on which to base a large volume item that must sell in a narrow-margin, competitive field. In addition to the fundamental price factor, glass is an electrical insulator and serves not only as the vacuum container, but permits the tube to be mounted in the set cheaply and with little danger of electrical leakage.

Method of Manufacture

Glass bulbs for small cathode-ray tubes, such as are used in oscilloscopes, are generally made by blowing in one piece. However, it is difficult to get the glass distribution and surface quality required for large bulbs by a blowing method. Therefore present-day large bulbs are made by a process which was originated by Corning Glass Works,[1] the first large-scale application being the production of large quantities of cathode-ray bulbs used during the war in radar equipment.

Briefly, the present method of manufacture consists in sealing together three separate parts. In Fig. 1 are shown the parts from which the popular 16⅝-in. rectangular bulb are made. The panel is made by pressing, which insures accurate control of face thickness and curvature. The middle section, or funnel, also may be made by pressing, or by a process of centrifugal casting. Cast funnels have the advantage of less

Presented on October 16, 1950, at the Society's Convention at Lake Placid, N. Y., by John L. Sheldon, Development and Research Dept., Corning Glass Works, Corning, N. Y.

weight. Drawn tubing is used for the neck, thus satisfying the rather stringent requirements imposed by close-fitting components that must slide over the neck, as well as the need for ample electron beam clearance inside. Further, an accurate, round bore insures accurate alignment of the electron gun.

A #4 Alloy "button" is sealed into the side of the funnel with fully automatic machinery. It serves to make contact with the conductive coating which is on the inside of the bulb. Successful button sealing goes back to the manufacture of the alloy. The analysis must be within close limits, as well as the expansion coefficient. Also, it must have proper oxidation characteristics. Before use, the button must have a special cleaning, followed by oxidation in wet hydrogen at about 1200 C. The oxide that is produced bonds to the glass during sealing to form a strong, vacuum-tight joint.

Formerly the three separate parts were joined by welding with gas fires. We now employ an electric method[2] for sealing panel and funnel together. It has the advantage that heat is generated within the glass, rather than "pushed" in from the outside. Also, the method is fast and easy to control, hence it is very well suited for mass manufacture. The result of electric heating is a seal that has excellent geometry and strength.

Because the finished tube is evacuated, and thus subject to external pressure, it must be strong. A factor of safety is necessary to guard against breakage when the tube is mishandled. Therefore it is customary to design bulbs to withstand a pressure of three atmospheres.

Glass Characteristics

One of the important developments of the past two years has been that of a new lead-free glass designed particularly for mass-produced picture bulbs. During the war lead glass was used for radar cathode-ray oscilloscope bulbs, partly because high electrical resistivity was needed. Lead has been an expen-

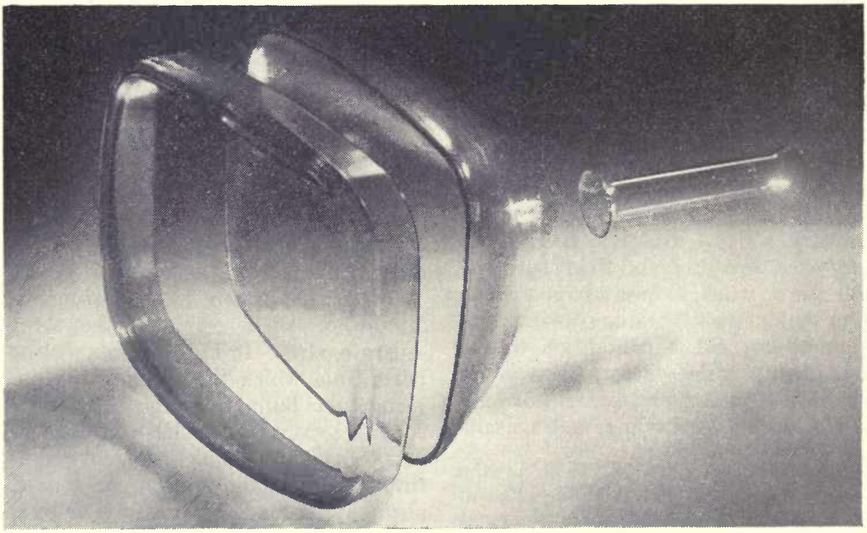

Fig. 1. Separate parts that are sealed together to make a bulb.

sive and uncertain material and because a substantial percentage was used, the bulbs were heavy.

A glass completely free from lead is of particular importance at this time when it is almost certain that restrictions will be placed on lead and other strategic materials. This is doubly important in view of the accelerated electronics program. Radar tubes can be made from lead-free glass to advantage; in fact, the optical quality of future radar tubes will be far better than those used in the last war. Military radar will also benefit from other substantial advances made in glass technology. During World War II most of the panels for radar bulbs were made by the laborious method of hand pressing. Now, high-speed pressing of 20-in. panels is routine.

The new glass (Corning Code 9010) was tailored to the exacting requirements of television. It has a high electrical resistivity, is 15% lighter than the lead glass formerly used (Corning Code 0120) and can be readily melted to give the exactingly high quality that is demanded in picture-tube panels. In Table I are some engineering data.

Table I

Density	2.59
Refractive Index (N_D)	1.506
Coefficient of Expansion (Average 0–300 C).	88.5×10^{-7} cm/cm/°C
Electrical Resistivity	
350 C	log 7.0 (ohms/cm)
250 C	log 8.9 (ohms/cm)
Softening Point . .	650 C
Annealing Point . .	442 C
Strain Point	411 C

Although it is important to control the properties of all electronics glass within narrow limits, this is particularly vital for television picture bulb glass. Close control of the expansion coefficient is dictated by the method of bulb manufacture, which requires very large seals between relatively thick "high" expansion glass. In this operation, two glass-to-glass and one glass-to-metal seals are required. Much of the time the separate parts are produced from different tanks. A third glass-to-glass seal is made by the tube manufacturer. Not only is expansion important, but so also are the viscosity characteristics. The "stem" carrying the electron gun is joined to the neck with a "drop" seal, in which the heated neck-glass is pulled down around the stem by gravity. This high-speed, automatic operation is dependent on close control of glass properties.

High electrical resistivity is desirable for several reasons. First, the full anode voltage appears across the wall of the neck tubing, from the inside conductive coating to the external components which are at ground. Second, in many types the outside of the funnel is coated with a conductive paint. Thus, the bulb also serves as a filter condenser, the glass wall being the dielectric. Last, if the resistance were low, then the tube mounting would have to be a good insulator to prevent excessive electrical leakage through the glass to ground. This would increase set cost.

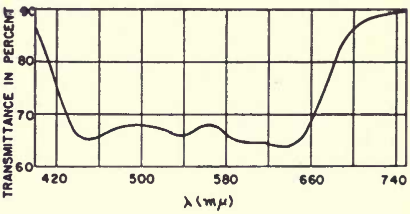

Fig. 2. Transmittance curve for Corning 9010 neutral-gray glass.

The first lead-free glass to be used was "clear." However, following an extensive program of development with the tube industry, a neutral gray version was offered in 1949. The spectral transmittance is shown in Fig. 2. Use of a

neutral absorbing glass minimizes the loss of contrast due to ambient light that falls on the screen.[3] This was an important contribution, because of the trend toward viewing television in lighted rooms and, also, because of the increase in the number of daytime programs. An absorbing glass also minimizes loss of contrast due to halation, which is the result of internal reflections within the face.[4]

At present there is an industry standard for luminous transmittance and chromaticity which was agreed upon by the Joint Electron Tube Engineering Committee (JETEC) of the RTMA (Radio and Television Manufacturers Assn.). For 10½-in. and 12½-in. bulbs the luminous transmittance is 66 ± 3%. The chromaticity is defined by use of the International Commission on Illumination color system. In Fig. 3 is shown a nominal spectral emission curve for the P4 7000° white phosphor used in television tubes, while Fig. 4 shows the tolerance area for chromaticity. The nominal chromaticity of the standard P4 phosphor-gray glass combination is $x = 0.3044$ and $y = 0.3177$, with a tolerance area as shown in Fig. 5. Considera-

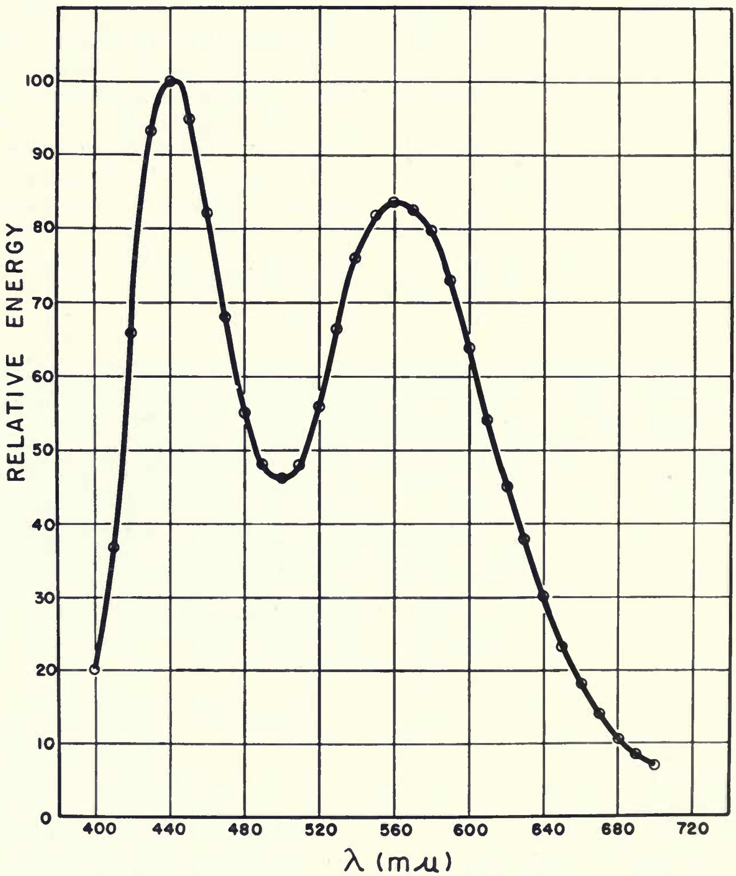

Fig. 3. Spectral energy emission characteristics of typical 7000 K all-sulfide P4 screen.

tion is currently being given to standardizing larger-sized bulbs.

Trends in Bulb Design

The phenomenal growth of television is matched only by the equally rapid rate of change within the art—a rate so great as to make most written material out-of-date before it can be published.

1. Size. In 1948 the 7-in. electrostatic and 10½-in. electromagnetic round tubes were the large-volume types. They were supplanted by the 12½-in. round tube in 1949, which in turn has become practically obsolete, being followed by 16-in. and 19-in. round bulbs. This evolution is shown in Fig. 6.

The ready acceptance of larger and larger pictures brought about the practice of "overscanning," which resulted in a picture with straight top and bottom sides, but with circular ends. While this increased the utilization of available screen area, there was a loss of the information in the corners and a departure from the 4:3 rectangular shape. This subject was recently discussed by Bretz.[5]

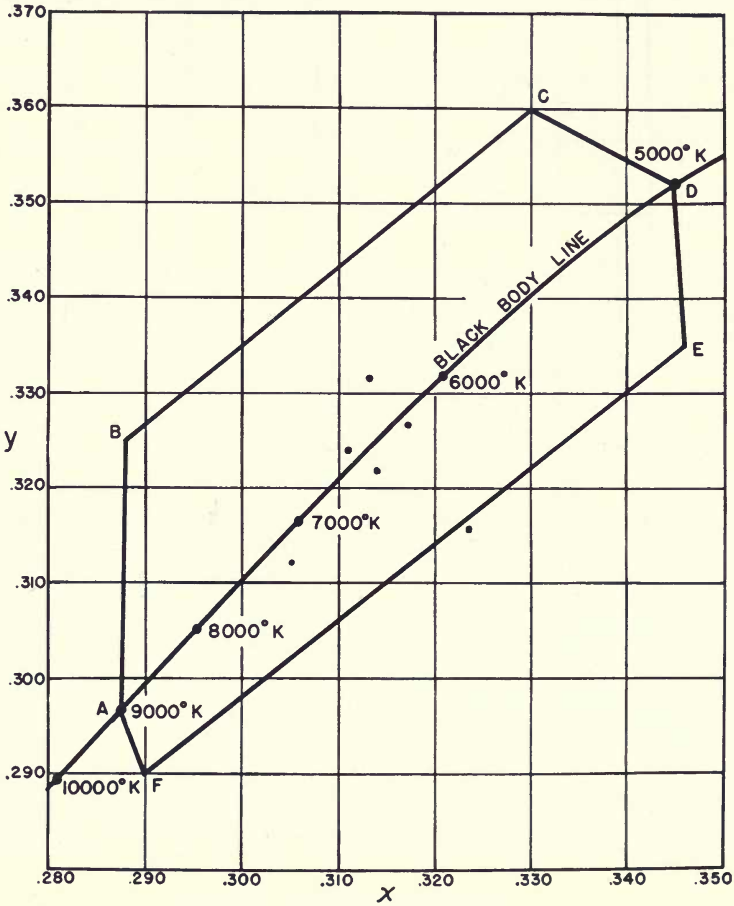

Fig. 4. JETEC color limits for P4 white phosphor.

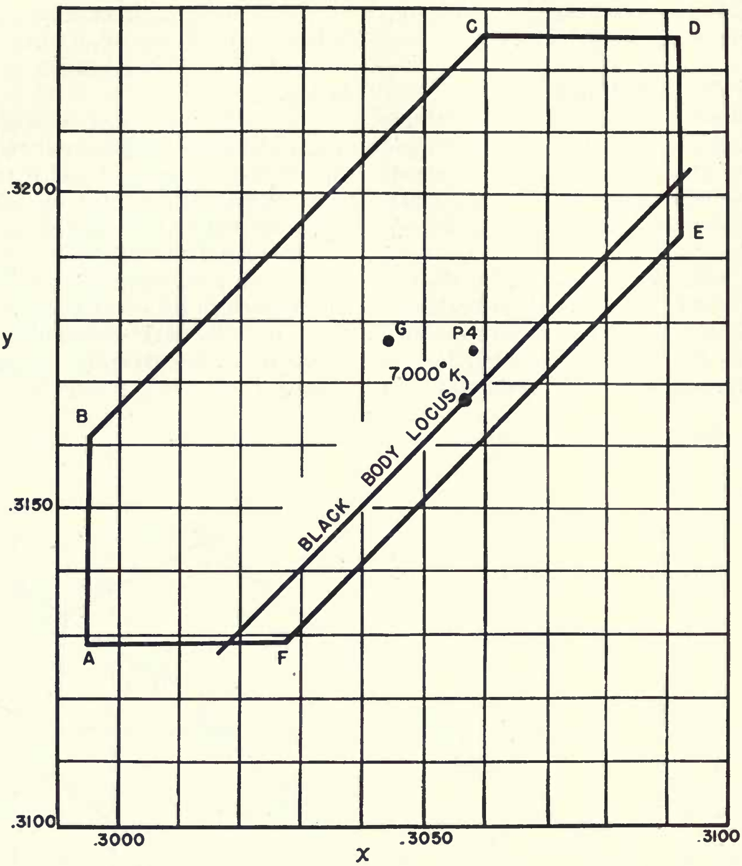

Fig. 5. JETEC specifications for neutral filter face glass.

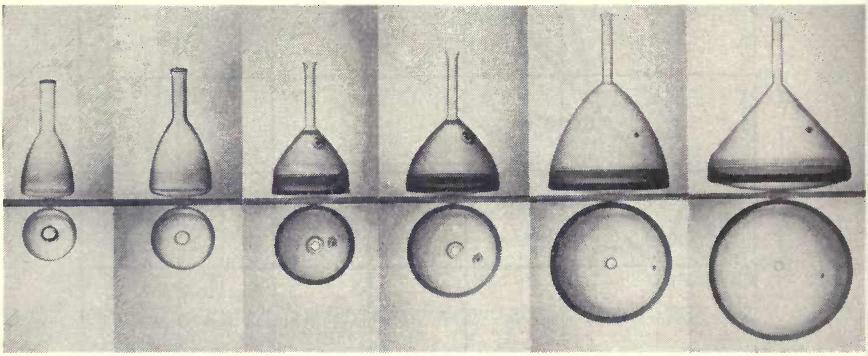

Fig. 6. Trend of bulb size, 1948–1950.

From left to right, 7-in., 8½-in. (both blown bulbs), 10½-in., 12½-in., 15⅞-in., 18⅞-in.

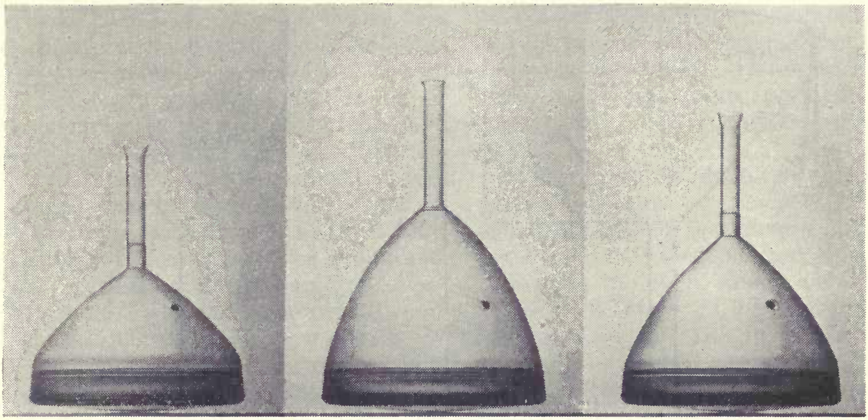

Fig. 7. Three 15⅞-in. bulbs
Left to right, 70°, 52° and 60° deflection angles.

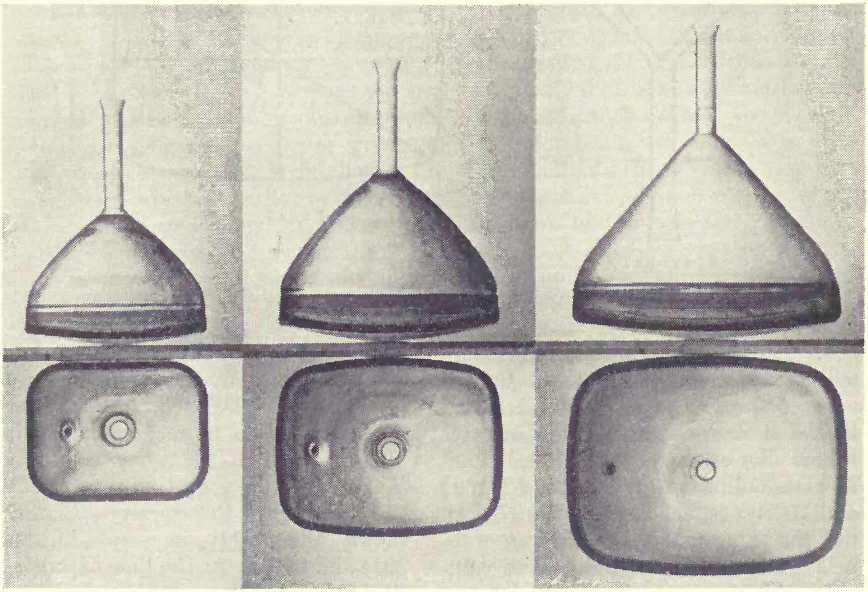

Fig. 8. Rectangular bulbs
Left to right, 13$^{11}/_{16}$-in., 16⅝-in., 20$^{3}/_{32}$-in.

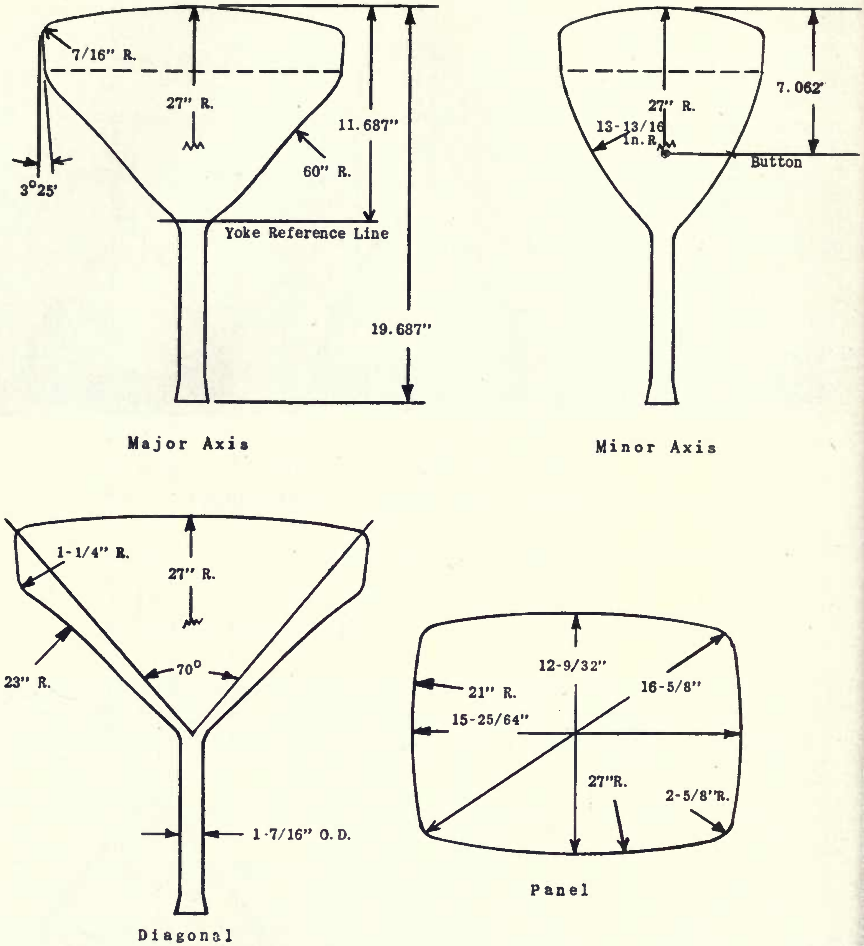

Fig. 9. Drawings of 16$\frac{5}{8}$-in. rectangular bulb.

2. Length. While round bulbs were still in use there was a trend toward wider deflection angles, which resulted in the desirable advantage of shorter tubes. For example, the 15$\frac{7}{8}$-in. round all-glass bulb has been made in 52°, 60° and 70° types, as shown in Fig. 7. All use the same panel, but different funnels. Shortening the bulb saves valuable cabinet space and this has become more important with the trend to larger sizes. At the time of writing, 70° is the commonly used deflection angle.

3. Bulb Shape. The somewhat dubious practice of overscanning in round tubes has now been corrected through the introduction of rectangular bulbs. We are sure that the return to the rectangular picture is gratifying to most of the members of this Society. Figure 8 shows the 13$\frac{11}{16}$-in., 16$\frac{5}{8}$-in. and 20$\frac{3}{32}$-in. bulbs. At the time of writing, the 16$\frac{5}{8}$-in. is a very popular type, although the demand for 20$\frac{3}{32}$-in. is increasing rapidly.

4. Dimensional and Other Considera-

tions. The rapid rate of change has brought with it an engineering challenge of some magnitude and the problems of designing and building equipment of increasing size have resulted in considerable progress in the art of glass making. The demand for better and better glass quality has led to frequent revision of specifications and we should not here attempt to go into the six or seven pages of specifications that cover a single type, except to say that the glass quality and dimensional standards have steadily increased. Some of the conventions having to do with dimensions may be of interest. In Fig. 9 are outline drawings of the 16⅝-in. rectangular bulb, which show some of the important dimensions.

A practice of long standing in the lamp and tube industry is to rate the size of *bulbs* by use of a number which is the maximum outside diameter in eighths of an inch. Rectangular bulbs are rated by the diagonal dimension. For example, the 16⅝-in. bulb shown in Fig. 9 is a C–133. When the bulb is registered with the American Standards Assn. the size designation is prefixed with the letter "J." *Tube* sizes are also based on the maximum outside diameter, or diagonal, and are given in inches, to the nearest inch. Tubes are registered with the Radio and Television Manufacturers Assn., which assigns a title. For example, one of the tubes made from the 16⅝-in. bulb is the 17AP4. The "A" is a serial designation and the P4 describes the phosphor.

Future Developments

We believe the rectangular shape is here to stay. The $20\frac{3}{32}$-in. size is becoming very popular, but it does not appear to be the end and a rectangular bulb with a diagonal in the mid-20's is on the drawing board. The ultimate size will probably be limited by economic considerations and certainly by the size of the average door. How much wider the deflection angle will go is a matter that depends more upon circuitry and component considerations than on glass manufacturing. However, the larger sizes will bring pressure to shorten the bulb through use of wider angles.

To date virtually all the tubes manufactured have gone into new sets. It is the writer's opinion that there is a place in the home for a medium-sized picture, perhaps in the 14-in. range, and that in the future there will be a return to this size. Such a set might well be the "second" one in the home.

As of October, 1950, there is considerable interest in the use of nonglare finish on the face of tubes. This is a slight matte finish which diffuses reflections and thus lessens the annoyance due to recognition of various objects or light sources that are seen by specular reflection in the untreated tubes. Such a finish must be carefully controlled to strike the best compromise between reduction of specular reflection and loss of resolution and contrast.

A more recent solution to the problem of annoying specular reflections is the use of panels that have a cylindrical, rather than spherical surface, the axis of the cylinder being vertical. It is obvious, from simple geometry, that in most cases the seated viewer will not see reflections of lights and objects that are above his eye level and, also, that further protection can be realized by tilting the tube downward a few degrees. As a result, the room can be easily lighted to a desirable level without the annoyance of reflections. Also, there is no loss of resolution or contrast as is the case with tubes having a frosted finish. Demonstrations of operating tubes were held for tube and set makers in New York and Chicago in late October and the results were very striking.

Acknowledgment. A. E. Martin, Sylvania Electrical Products, Inc., very kindly furnished illustrations used in Figs. 3, 4 and 5.

References

1. Huston Harris, U.S. Pat. 2,160,434.
2. E. M. Guyer, "High frequency electric glass welding," *Trans. Electrochem. Soc.*, vol. 79, pp. 187–198, 1941; "Electronic welding of glass," *Electronics*, vol. 18, pp. 92–96, 1945.
3. Alfred E. Martin and Robert M. Bowie, "Picture-tube contrast improvement," *Electronics*, vol. 23, pp. 110–112, Aug. 1950.
4. R. R. Law, "Contrast in kinescopes," *Proc. I.R.E.*, vol. 27, pp. 511–524, 1939.
5. Rudy Bretz, "The shape of the television screen," *Jour. SMPTE*, vol. 54, pp. 545–553, May 1950.

Discussion

Mr. Seeley: Would the author say a few words about glass tubes as compared with metallic tubes, with regard to the results that can be obtained and the cost of production?

Dr. Sheldon: I am not prepared to discuss the production costs. The performance is a matter of tubes, and I think that is a question that might more properly be answered by one of the tube people. So far as I know, there is no essential difference in the performance, once the tube is installed in the set. However, all-glass tubes have certain advantages as regards mounting in the set.

Anonymous: What is the minimum reflection on the face of a 20-in. tube—the minimum arc across the surface?

Dr. Sheldon: You mean the panel radius?

Anonymous: That is right.

Dr. Sheldon: The outside panel radius is 40 in.

Anonymous: What is the chord across the curved surface of the face of the tube?

Dr. Sheldon: Across the maximum diagonal? That is about 1½-in. less than that (20 in.), approximately. That takes care of the thickness of the glass and the radius.

ABSTRACT

Stereo-Television in Remote Control

By H. R. Johnston, C. A. Hermanson, and H. L. Hull

The study of the possibilities of using three-dimensional television in conjunction with remotely controlled electric manipulators is part of a long-range development program being undertaken by the Remote Control Engineering Division of the Argonne National Laboratory.

Manipulation of objects in three dimensional space requires that depth perception be incorporated into any scheme used to view and control the means of manipulation. It is not sufficient to use ordinary two-dimensional television for this purpose since the ability to judge depth is almost entirely lacking.

A standard Du Mont television pick-up chain was employed in the development of stereo-television. The stereoscopic pair of images are placed side by side by a twin lens system onto the photocathode of the television camera tube. The images occupy the same space on the photocathode as a single image in standard two-dimensional television and they are transmitted simultaneously. At the receiving end of the stereo-television system, the two images appear side by side on the face of a standard kinescope or television picture tube.

Two polarizing filters whose axes of polarization are at right angles to each other are placed immediately in front of the images on the cathode-ray tube. An observer wears a pair of polarizing spectacles so oriented that the right eye is permitted to see only the right-eye image and the left eye sees only the left-eye image.

A second method used to view the three-dimensional television pictures makes use of two television picture tubes. These tubes are arranged at right angles to each other and a semi-transparent mirror is placed so that it is at 45° with both tubes. Crossed polarizing filters are placed in front of each picture tube and the observer wears crossed polarizing spectacles. The observer is enabled to see the three-dimensional image by observing one image by transmission through the semitransparent mirror and the second image by reflection.

To test adequately the possibilities of the stereo-television system as a means of seeing objects in three-dimensional space, two mechanical Master-Slave manipulators were arranged so that the operator sat with his back to a wall, behind which the slave hands and the stereo-television were located. The operator faced the stereo receiver and saw a three-dimensional image of the manipulator "slave" hands and objects in the work area, while with his hands in the "master" controls he manipulated objects in the field of view. After a few

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Abstract by Pierre Mertz of a paper presented on September 26, 1950, at the National Electronics Conference at Chicago, Ill., (in which the SMPTE Central Section participated), by H. R. Johnston, C. A. Hermanson and H. L. Hull, Argonne National Laboratory, P.O. Box 5207, Chicago 80. The complete paper was published in *Electrical Engineering* for December, 1950, and will also be published in *Proceedings of the National Electronics Conference*, vol. 6 (for 1950).

minutes of indoctrination any person with normal vision can be taught to see and manipulate the objects in view from a remote distance. In another setup, an electrically operated manipulator was made to perform miscellaneous feats of lifting objects and pouring liquids from one beaker to another, while the operator controlled its movements from another room over 50 ft away.

The present system of stereo-television using one camera pickup tube, gives a stereo picture which has an aspect ratio of three high and two wide. This may be undesirable for use in any permanent installation. In addition, the field of view is restricted, and the resolution is adversely affected.

A more desirable system would consist of the use of two television camera pickup tubes arranged side by side in a horizontal direction. The left pickup tube would supply a left-eye view to one of the receiving tubes of the dual viewer and the right pickup tube would supply the video signal for the second receiving tube.

ABSTRACT

The Orthogam Amplifier

By C. L. Townsend and E. D. Goodale

For some time it has been known that iconoscope film pickup tubes[1,2] do not produce video voltages ideally suited for reproduction by a normal kinescope unless gradient correction is applied. A re-evaluation of the transfer characteristic required in the television transmission system for optimum picture quality was undertaken, to include conditions actually encountered in normal commercial broadcast operation.

A series of slides was produced, each having an "average gray" background (density about 1.2) and, centered in that area, a rectangular "window." Each slide was made with a different window density, to cover the range normally encountered in practice. The slides were projected in succession, and in such a way that the same portion of the mosaic was used for each window. Oscilloscope readings of the voltages so generated showed a reasonably linear relationship with window density.

To determine the characteristic which is actually obtained in the existing recording-reproducing system, the "window" test was again used. A video voltage, representing the window and an appropriate background, was fed to the recording system. The amplitude of the voltage of the window proper could be precisely controlled to produce any value within the normal recording range, plus some excess into overload values, if desired. A recording was made of this signal, and the film processed normally. That film was then reproduced on an iconoscope system, and the output voltage values noted on an oscilloscope.

Abstract by Clyde R. Keith of a paper by C. L. Townsend and E. D. Goodale, Engineering Dept., National Broadcasting Co., Inc., RCA Bldg., Radio City, New York 20, published in *RCA Review*, vol. 9, no. 3, pp. 399–410, Sept. 1950.

The resulting plot is shown in Fig. A [Fig. 3 in original paper], and includes a wider range than is normally used. A serious compression of white-range voltages is present. All transfer characteristics of the intermediate recording and reproduction steps also were plotted with significant information produced at each point. Exposure and processing methods were altered in an effort to reduce the undesirable effects shown in Fig. A, but the general characteristic remained.

An analysis of Fig. A indicates that some nonlinear compensation is needed for both direct film and kinescope recording reproduction. The two cases differ as to amount required, but are otherwise generally similar. Both are simple curves, and compensation should be feasible.

Many times in the past "gamma correction" amplifiers have been built which had variously shaped transfer characteristics. Most of these actually compressed one part of the characteristic in order to get a relative expansion of another. Figure A indicates that the "black" half of the characteristic should not be altered, but rather an expansion in the "white" range is required. No *gradient* change should be permitted in the near-black signals, even though their relative amplitude is reduced to permit white expansion.

With the above requirements in mind, the Model "A" orthogam amplifier was designed with two parallel amplifiers, as indicated in Fig. B [Fig. 4 in original

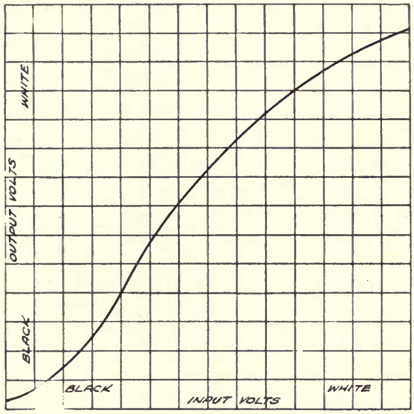


Fig A. Volts input to kinescope recording versus volts output from film reproducer.

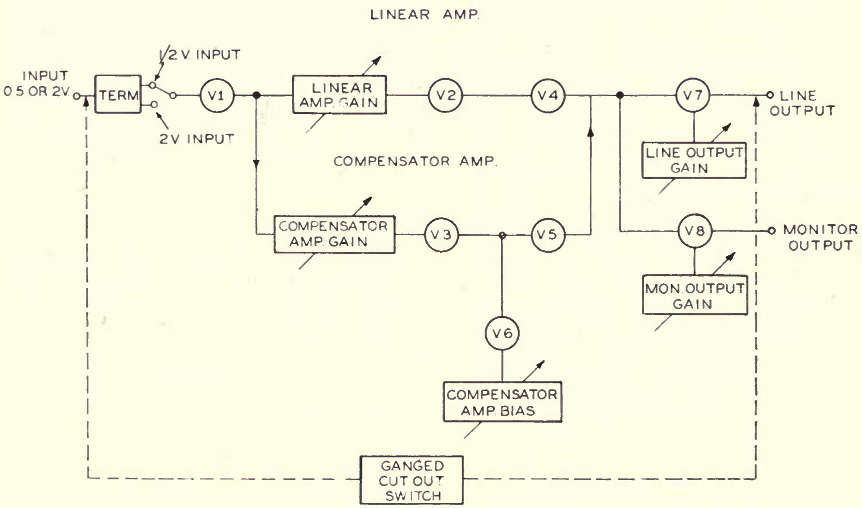


Fig. B. Block diagram of Model "B" orthogam amplifier.

paper]. The upper branch path provides a completely linear output voltage, to which the lower branch adds expanded white voltages. Large video voltages can be fed to V5, and its bias can be controlled to allow only the highlight tips of those voltages to be passed by the tube. Thus both amount and gradient of the correction can be controlled, without causing nonlinear operation in the black region.

Six orthogam Model "A" amplifiers were put into operational service as an extended performance check. "In-Out" tests immediately gained the cooperation of the operating personnel. Noticeable improvement in film transmission quality was commented on by observers not familiar with the tests. As an unexpected dividend in many cases the effect of flare was reduced, since in normal operation most of it occurs at low amplitude in dark areas, and the orthogam reduces the relative amplitude of such voltages. However, it shortly became apparent that some changes in the method were required. Operating crews found the units were "wild"—that is, they made video level riding difficult. This was found to be due to the fact that once a correct gradient was chosen for the normal maximum voltage level, much steeper gradients existed above that point, in the nominally unused region of overload. Frequently a video voltage peak would rise into that region and the additional amplification there would drive it far higher than it would otherwise have gone. Subsequent reduction of system gain corrected the matter, but only after a troublesome transition period. With close attention during rehearsal, and constant vigilance during broadcast, these effects could be acceptably minimized, but final judgment was that the Model "A" was not an operationally desirable tool.

Based on the above results, a new attack on the problem was made. Using the same basic philosophy of correction, it was decided that the major additional requirement was that the top desired gradient must be the greatest actually encountered in the system under operating conditions. Thus, instead of a continuously rising gradient in the overload-voltage region, the new orthogam must be linear at the steepest desired slope. This objective has been achieved in the Model "B" orthogam amplifier. [A circuit schematic and description are given in the original paper.]

Several NBC film studios now have been equipped with Model "B" units, and considerable operational experience indicates that the gainriding difficulty experienced with the "A" model has been largely overcome and substantial improvement provided in the transfer characteristic of the over-all system. This is evidenced in the viewed picture by a reduction in the chalkiness of faces and an improvement in the separation between other white and near-white portions of the reproduced image. The average brightness of the picture is reduced somewhat due to the fact that the a-c axis has been pushed towards the blacks. The end result is a more natural and pleasing reproduction.

References

1. O. H. Schade, "Electro-optical characteristics of television systems," *RCA Rev.*, vol. 9, nos. 1, 2, 3, 4, Mar., June, Sept., Dec., 1948.
2. D. G. Fink, "Brightness distortion in television," *Proc. I.R.E.*, vol. 29, no. 6, June 1941.

Diffuse and Collimated T-Numbers

A Review and Description of New Equipment

By Allen E. Murray

The SMPTE Subcommittee on Lens Calibration has formally recognized, through incorporation in its report, two methods of lens calibration. While they reach equivalent results and will calibrate lenses identically when properly safeguarded, each has its own shortcomings and advantages, which are not commonly recognized. To dispel the evident misunderstandings about these two methods, they are compared and the reasons are indicated for the method chosen. New equipment designed by Bausch & Lomb Optical Co. for lens calibration based on the diffuse method is described briefly.

From the interdependence of physical phenomena it follows that a given quantity can be measured in more than one way. The more fundamental it is, the larger is the number of its interrelationships and the larger the number of methods available for its evaluation. In the realm of pure physics this principle is put to use in assuring consistency of theories and the correctness as well as the limits of accuracy of fundamental constants. On the engineering level it assures, in addition, the solution of virtually any problem that may be raised, since it provides alternative procedures for finding the solutions, as well as checks on their correctness.

Presented on October 19, 1950, at the Society's Convention at Lake Placid, N.Y., by Allen E. Murray, Scientific Bureau, Bausch & Lomb Optical Co., Rochester 2, N.Y.

It is interesting to note that there is also a complementary principle at work: the principle of uniqueness of experimental arrangements and implications. This requires that the results obtained from given experimental equipment be specific to that equipment and issue only from the principles it employs. The distinctions thereby created may in many cases be without a difference, but the possibility of alternative methods of accomplishing things implies that the things done are not identical in detail.

These observations are prompted by the recent history of photometric lens calibration. This problem reduces, in essence, to the measurement of the illuminance in the image plane of a lens under such conditions that the transmittance and relative aperture are evaluated together. This requires, in principle, that the illuminance at a particular stop be compared with the

illuminance produced by an ideal lens or its equivalent at a similar stop. Within the limitations of the general method there is a large number of procedures capable of meeting the requirements of accuracy and obedience to essential physical principles. These procedures are not all equally reliable or sound, and each measures the illuminance under a different set of circumstances, i.e., measures a quantity which, though related, is not always the one wanted.

All these considerations were in the collective mind of the Society's Subcommittee when it prepared its report[1] and, in Appendix II, discussed two general experimental procedures whereby the T-number could be evaluated. The Subcommittee, however, understandably failed to point out that of all physical procedures, the photometric are among the most treacherous, in that even when the principles are correctly applied, it is disconcertingly easy to commit some simple error of omission, failure to eliminate every last trace of stray light for instance, vitiating the whole procedure. The extent to which extremely careful attention must be paid to every safeguard in photometric practice is not realized by those unfamiliar with photometry, and as a result many proposals of unequal merit have been published from time to time.

The Subcommittee also failed, and equally understandably, to point out that the two methods, being different *ab initio*, must evaluate different physical quantities, and moreover each must have its own set of shortcomings and advantages.

The Subcommittee was following historical precedent when it chose to describe the collimated and the diffuse source methods, for the published procedures have fallen naturally into the same two classes. These published methods are included here for their historical interest, and are further classified according to whether the light is sent in the normal or counter direction through the lens:

I. Collimated Source

Normal	*Counter*
Silvertooth[2]	Odencrants[5]
Daily[3]	Hrdlicka[6]
Townsley[4]	

II. Diffuse Source

Normal	*Counter*
Lambert[7]	Berlant[14]
McRae[8]	Murray[15]
Moffitt[9]	
Clarke & Laube[10]	
Sachtleben[11]	
Gardner[12]	
Back[13]	

A balance sheet of the several advantages and disadvantages in principle and practice can be drawn up without difficulty. After noting that the collimated methods in effect evaluate a quantity proportional to the diameter of the entrance pupil of the objective, while the diffuse methods evaluate the flux on the image side of the lens, an unimportant distinction for most purposes, the two methods can be compared on their merits as procedures yielding the T-number defined by the Subcommittee.

I. Collimated Source

Advantages

1. Focusing unnecessary
2. Lens always correctly focused
3. Little power required in source

Shortcomings

1. Knowledge of equivalent focal length of lens essential
2. Requires different set of apertures for each focal length or calibrating means such as Townsley's[4]
3. Theory more complex
4. Indirect measurement of T-number
5. Uniformity of collimated beam is troublesome to ensure; the effect of beam spread is difficult to evaluate
6. Not directly adaptable to finite magnifications
7. Entrance pupil diameter limited by collimator lens

II. Diffuse Source

Advantages

1. Focal length knowledge unnecessary
2. Adaptable to any magnification (with focal length known)
3. More fundamental and thus simpler in principle
4. Maximum lens aperture unlimited

Shortcomings

1. Focusing essential
2. Attainment of uniform source quite difficult
3. Light losses large—high sensitivity in detector or great power in source required

The criticisms are readily seen to be unequal in weight, numbers 3 and 4 under the collimated source being minor objections in the theory, while 2 and 5 can be overcome by careful engineering. The most serious of these shortcomings are perhaps 6 and 7, and in this order. It is no trick to measure the equivalent focal length accurately enough (1), but the limitations to lenses of a given diameter and always at a fixed magnification are real handicaps. The collimated source method demands that the collimator lens always be larger than the entrance pupil of the lens being tested, and this requires costly lenses in larger sizes. The author knows of no simple way of adapting this method to finite magnifications.

The advantages of this method are all substantial: to have the lens under test automatically and securely focused undeniably creates confidence, and the convenience of a light source whose power requirements are small is not to be denied.

Except for the first, the shortcomings of the diffuse method are serious enough to demand the most careful engineering. Focusing is easy; it can be done by autocollimation or by the use of a telescope. It demands considerable engineering effort, however, to ensure an extensive diffuse source whose uniformity is sufficient to meet the requirements, and in addition sound design to attain useful sensitivity with reasonable power input into the lamphouse.

Numerous methods of assuring uniformity with diffusion have been proposed. Perhaps the best is the one proposed in the Subcommittee Report, using a sheet of direct-light shielded ground glass to cover the aperture in a matte white box. Even at best, however, these lamphouses must be large, since it is necessary that the T-stop equivalent solid angle be filled with flux at all values. Fortunately the measurements are independent of the source distance when the incident cone is filled.

The advantages of this method counterbalance the disadvantages. It is clear that adaptability to all magnifications and no restrictions on lens aperture together make up a strong argument in its favor.

These considerations seemed to us to be so cogent that when we designed the equipment to conform with the Subcommittee recommendations, we chose the more fundamental diffuse source procedure. Our equipment was specified to be null reading, in order to remove all questions of photocell response linearity and as nearly as possible to compare unknown with standard aperture simultaneously, in order to avoid any possibility of faulty mechanical or electrical memory.

Both objectives have been realized (Fig. 1) by providing two apertures into the integrating box which illuminates the detector photocell. These apertures are alternately opened and closed thirteen times per second, so that the same total area is free to the lamphouse at all times—first, all of one aperture, and as this closes, the other opens synchronously to completion. Thus when the flux incident on the two apertures is the same, there is a constant light level within the box. When, however, one aperture is blocked completely, the light level varies as the size of the uncovered aperture, sinusoidally in this equipment.

The two functions of the phototube and the electronic circuit are then to detect the state of light balance and to measure the degree of unbalance. Figure 2 illustrates the principle of measurement, while Fig. 3 shows the schematic electric circuit.

It is clear that balance comes about electrically when the amplitudes of the 13-cycle signals arising from the two apertures are equal, for then, since they are phased 180° apart, the resultant signal is constant.

The dominant aperture in the general case will phase the light signal. To determine which aperture this is and to produce a deflection at light balance, an auxiliary bipolar generator is synchronized with one aperture, and the measuring circuit designed to evaluate the sum of the light and generator signals. By adjusting the circuit properly, the indicator can be placed at midscale with only the alternating component of the generator effective so that deflections to

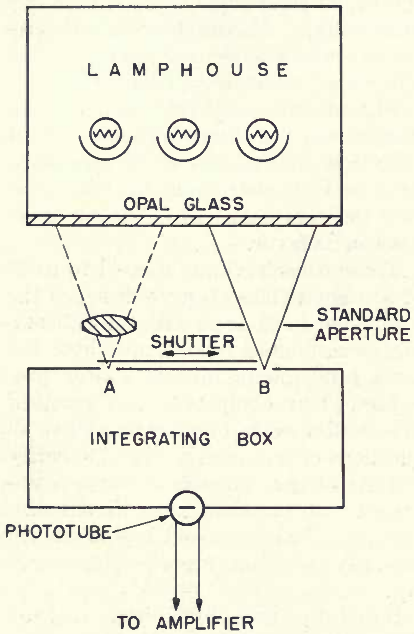


Fig. 1. Schematic optical layout.

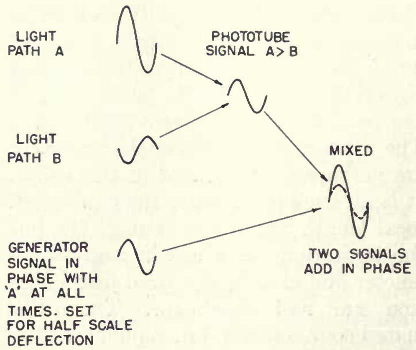


Fig. 2. Principle of measurement.

When A > B resultant mixed signal is > half scale

When A = B resultant mixed signal is half scale

When A < B resultant mixed signal is < half scale

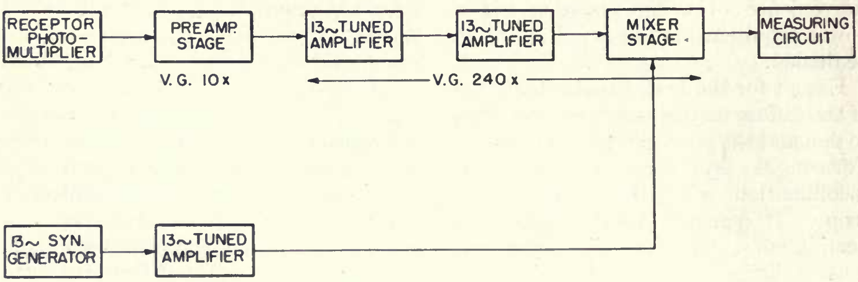


Fig. 3. Schematic electrical circuit.

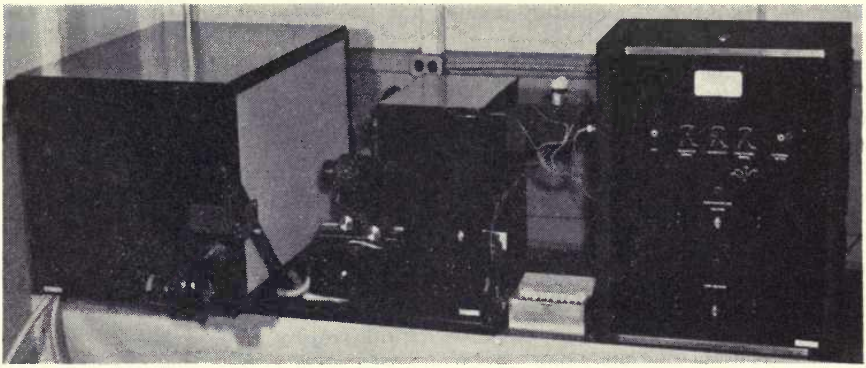


Fig. 4. General view of equipment.

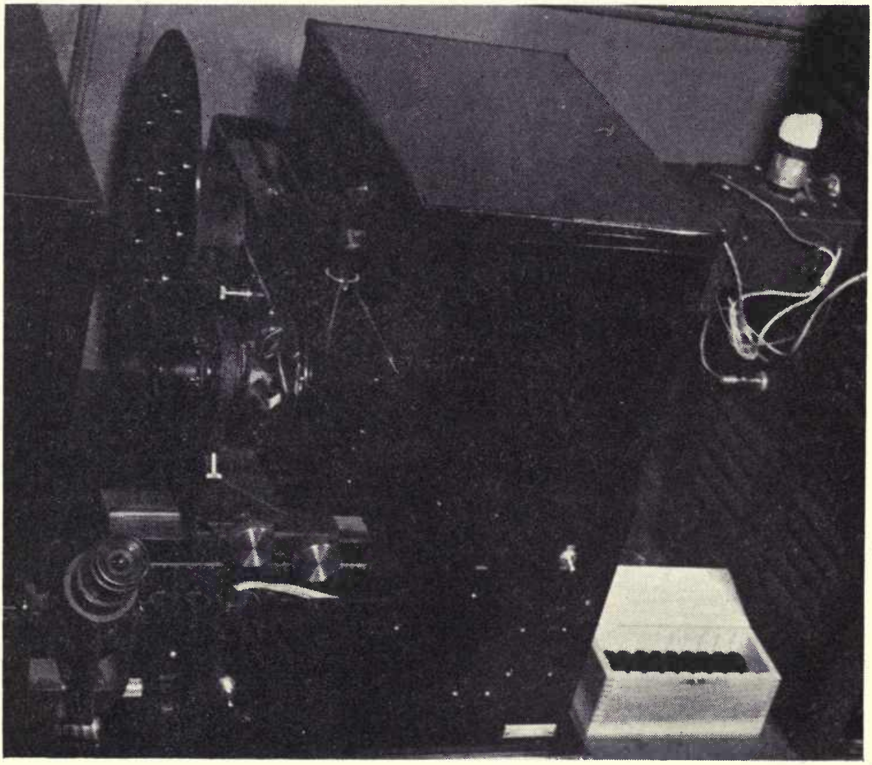


Fig. 5. Lens Mount and Standard Aperture Turret.

the right mean that one aperture dominates, and to the left, the other.

Moreover, by the use of the auxiliary calibrating apertures it is possible to calibrate the meter in terms of T-numbers between each two consecutive full stops, and thus interpolate between stops for measurement or calibration purposes. This eliminates the need for neutral density filters.

A general view of the equipment is contained in Fig. 4, and Fig. 5 shows the front of the integrating box. The lens standard carries a scale and vernier, which make it useful for measurement at finite conjugates. This scale is indispensable for maintaining or checking on the calibrations and sensitivity.

The T-stops are defined by apertures placed a fixed distance from the integrating box aperture and carried on a turret plate. These are duplicated in a loose set of apertures fitting into an adapter in the lens standard.

The illumination at present is provided by a large lamphouse containing three 500-w projection lamps. It is coated white inside, and the front face is a large sheet of flashed opal glass. The uniformity of luminance of the face just meets the specifications contained in the Subcommittee Report. Some other arrangement doubtless would be safer in future equipments.

This particular calibration unit has proved to be quite handy in practice, more than adequately sensitive with the focal plane apertures for the 35-mm and 8-mm frames, with the 1P22 photomultiplier tube and three accelerating potentials, and self-contained in that it calibrates itself with the help of the auxiliary apertures and basic instrumental dimensions.

The reproducibility of measurement at all stops is of the order of less than 1%, and the accuracy certainly well within the allowed ±7% in illuminance.

Acknowledgments: An enterprise such as this is the result of group effort, and therefore it is necessary to distribute the credit for the design of this equipment. The mechanical design was ably carried out by R. Filsinger under the direction of O. Boughton, while the electronic circuit is the result of the joint efforts of K. H. Bloss and A. A. Shurkus, assisted by W. Ehlers. The mechanical assembly was under the direction of W. Guenther. The author also wishes to acknowledge the help given in conversations with his colleagues, in particular Dr. K. Pestrecov and G. C. Wooters.

Bibliography

1. "Report of the SMPTE Subcommittee on Lens Calibration," *Jour. SMPE*, vol. 53, pp. 368–378, Oct. 1949.
2. E. W. Silvertooth, "Stop calibration of photographic objectives," *Jour. SMPE*, vol. 39, pp. 119–122, Aug. 1942.
3. C. R. Daily, "A lens calibrating system," *Jour. SMPE*, vol. 46, pp. 343–356, May 1946.
4. M. G. Townsley, "An instrument for photometric calibration of lens iris scales," *Jour. SMPE*, vol. 49, pp. 111–122, Aug. 1947.
5. A. Odencrants, "A new method for the determination of the true transparency of photographic objectives," *Science et Industries Photographiques*, vol. 6M, p. 57, Nov. 1926.
6. J. Hrdlicka, "Measuring the effective illumination of photographic objects," *Jour. SMPE*, vol. 14, pp. 531–533, May 1930.
7. J. H. Lambert, "Ostwald's Klassiker der Exakten Wissenschaften," Nr. 31, Part 2, Chapters III and IV, Engelmann, Leipzig, 1892.
8. D. B. McRae, "The measurement of transmission and contrast in optical instruments," *J. Opt. Soc. Amer.*, vol. 33, pp. 229–243, April 1943.
9. G. W. Moffitt, "Determining photographic absorption of lenses," *J. Opt. Soc. Amer.*, vol. 4, pp. 83–90, May 1920.
10. D. B. Clarke and G. Laube, "Twentieth Century camera and accessories," *Jour. SMPE*, vol. 36, pp. 50–64, Jan. 1941; also U. S. Pat. 2,334,906, 1943.

11. L. T. Sachtleben, "Method of calibrating lenses," U. S. Pat. 2,419,-421, 1947.
12. I. C. Gardner, "Compensation of the aperture ratio markings of a photographic lens for absorption, reflection, and vignetting losses," *Jour. SMPE*, vol 49, pp. 96–110, Aug. 1947; also *J. Res. Nat. Bur. Stand.*, vol. 38, pp. 643–650, June 1947.
13. F. G. Back, "A simplified method for precision calibration of effective f-stops," *Jour. SMPE*, vol. 49, pp. 122–130, Aug. 1947.
14. E. Berlant, "A system of lens stop calibration by transmission," *Jour. SMPE*, vol. 46, pp. 17–25, Jan. 1946.
15. A. E. Murray, "The photometric calibration of lens apertures," *Jour. SMPE*, vol. 47, pp. 142–151, Aug. 1946.

The following three references are of historical interest:

16. C. Forch and E. Lehmann, "Die Lichtverluste in photographischen Objectiven," *Kinotechnik*, vol. 10, pp. 3–7, Jan. 5, 1928.
17. A. Klughardt and H. Otto, "Lichtstärkemessung hinter photographischen Objectiven den Kleinbild Kamera," *Photographische Industrie*, vol. 34, pp. 608–610, May 1936.
18. A. Kochs, "Lichtstärke und relative Offnung von Kine-Objectiven," *Kinotechnik*, vol. 22, pp. 154–157, Nov. 1940.

Discussion

M. C. Townsley: Is your instrument primarily intended for calibrating apertures or measuring apertures?

Mr. Murray: Actually, of course, the equipment does both. It was designed primarily to calibrate, but we picked up facilities here and there in the course of the design of the equipment. We are more than pleased that it will serve both functions.

Mr. Townsley: It looked from the way it was laid out that it could do both and probably do them quite well.

Mr. Murray: We have felt from the very beginning that calibration alone would not be sufficient. We wanted to be able from our own equipment, independently of any other, or from fundamental geometry and mechanical construction, to determine that the calibration is done properly.

Mr. Townsley: In calibration, I am thinking of starting with an unknown lens and marking a set of apertures in T-stops.

Mr. Murray: We can do that very well for the standard apertures on the turret plate. Their distance from the obscuring aperture in the lamphouse is known to around two tenths of one per cent. The diameter of each aperture has been measured along at least four meridians, so that we know they are circular. Their edges have been specially treated to cut down reflection. We put in what refinements we could see.

Mr. Townsley: I rather hope for the future of the T-stop system that you will do a great deal of original calibration on customer lenses on that system—actually mark them in T-stops.

Mr. Murray: I am authorized to say that this equipment will be used also for customer lens calibration. Our sales department has just let me know that we are ready to undertake this sort of work. You personally might be interested to know that we have had the opportunity to look over some of your lenses, and we are very pleased to note that we agree very closely.

This paper was prompted by some question as to whether one method is better than another. We must say "no." There is no visible justification for setting up a standard around one particular device or method. Any equipment is satisfactory as long as it conforms to physical principles and the requirements of sound engineering.

The Differential Carbon-Feed System for Projection Arc Lamps

By Arthur J. Hatch

There is a growing recognition of the fact that to obtain constant screen color and light intensity, the position of the positive carbon must be maintained automatically in relation to the projection lamphouse optical system. In the development and application of such a control feature, the requirements of carbon-feed systems have been reviewed. The differential carbon-feed system seems to meet these requirements, and considerations pertaining to the application of the differential feed system with automatic positioning to an angular trim burner will be related.

The challenge offered by present large screens, and the demand for higher picture brilliancies have led to the wide adoption of high-speed projection lamphouse optics, and carbons with higher intrinsic brilliancy.

With these the allowable tolerance in carbon crater position has been reduced by the use of the higher-speed lamphouse optics, while the difficulty of maintaining the arc crater at a given position has been increased by the high brightness carbons with their higher burning rates. These higher burning rates are unfortunately accompanied by greater fluctuations of burning rate with small current changes. These factors have made it desirable to incorporate automatic means in the carbon feed to maintain the position of the positive crater accurately to the lamphouse optical system.

This problem of providing automatic positioning to the positive crater of high-intensity projection arc lamps has necessitated a review of the requirements for carbon feeds, as such a positioning control cannot be conveniently or effectively inserted into the type of feed mechanisms in general use at present. Accordingly, to utilize an automatic positioning device it has been necessary to develop a new carbon-feed system.

To anyone not especially acquainted with operation or design of projection arc lamps, the feeding of the carbons would seem a very simple matter that could readily be solved by merely arranging a motor drive to both carbons. However, as it is with so many other seemingly simple problems, this subject is not altogether simple when the complete requirements are known.

Presented on April 27, 1950, at the Society's Convention at Chicago, Ill., by Arthur J. Hatch, The Strong Electric Corp., 87 City Park Ave., Toledo 2, Ohio.

Requirements of Carbon-Feed System

We find that the principal end results desired are uniform and constant intensity of screen illumination with constant color temperature. These results should be obtained through a carbon-feed system that has simple control adjustments and which is capable of self-compensation for changes in the variables, without attention from the projectionist.

Upon examining these requirements for a feed system, we find that the major electrical controlling factor necessary to obtain constant screen illumination, with a given carbon trim, is constant arc amperage.[1] With proper arc circuit ballast, the arc amperage will assume a value such that the sum of the positive and negative carbon-burning rates, at that arc current, equals the sum of the positive and negative feed rates. Then assuming for the moment that the carbon-burning rates are constant for a given current, it will be readily seen that a constant total feed rate will provide most even illumination.

Therefore, a very simple carbon-feed mechanism could be constructed which would advance the relative positions of the carbon holders one to the other at the constant rate necessary to maintain the desired current.

The negative carbon could stand still and the positive carbon could be advanced at a rate equal to the total burning rate of both carbons; or the positive could stand still and the negative could advance at the total rate. Any number of positive and negative feed ratios could be used as long as the combined feed added to the figure desired for total feed.

This simple feed, however, would not take into account the fact that to utilize the illumination from the carbon arc for projection, the positive crater must be kept at the exact entrance focal position of the lamphouse optical system. It is, therefore, necessary to make provision to divide the total feed into positive and negative feeds, in a proportion exactly equal to the positive and negative burning rates at the particular current desired, in order to maintain the position of the positive crater to the optical system.

This division of the total feed into its components needs to be flexible, unless the lamp is to be burned at a single current, as the ratio between positive and negative burning rates varies considerably through the current range of the carbons.[2]

The operation of this ratio-fixing control should not affect the sum total feed rate of the positive and negative carbons. For this reason a ratio-changing system is necessary in which, if the negative feed is slowed down, the positive feed is increased simultaneously so that total carbon feed and constant current are maintained.

An Ideal Feed System

From the foregoing it is easy to draw a conclusion that an ideal feed system would be one in which one control determined the total feed and the other control determined the ratio between positive and negative feeds. With a system of this type, the total feed control could be set for the desired amperage and the ratio control adjusted until the feed ratio matched the burning ratio. This second adjustment would not affect the feed-control setting.

Thus, for example, with a 7-mm negative and 8-mm positive copper-coated high-intensity trim the total burning rate for both carbons at 70 amp is approximately 20 in./hr. The current selector would be set to produce this total rate of feed. Then the ratio control would be adjusted, until the position of the burning tip of the positive carbon in relation to the optical system was correct and its relative movement reduced to zero. It thus might be found necessary to adjust the ratio control

setting so that the negative feeds 4 in./hr, and the positive, 16 in./hr, or the negative might be fed 4¼ in./hr, and the positive, 15¾ in./hr. In either case the total feed would remain at 20 in./hr. and the arc current at 70 amp.

This ideal feed system is analogous to that of a mechanical differential system, a common type of which is found in the rear drive of automobiles. Here the speed of the torque tube drive shaft is analogous to the total feed of both carbons. The sum of the drive of the two rear axles is a constant for constant-torque tube drive and the ratio between axles can be varied by restraining one wheel in which case the other wheel turns faster.

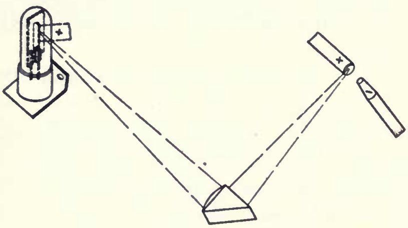


Fig. 1. Carbon position-detecting optical system showing prism lens and bimetallic switch.

A practical embodiment of this ideal feeding system can be realized with the use of a two-motor drive. One motor, which is the feed motor, drives both carbons through a differential gear drive. The second, or rate-control motor, is connected preferably in the negative drive. The resultant difference in drive between the feed motor and the rate-control motor is transmitted to the positive carbon feed. Gear ratios are chosen so that the resultant total feed of both carbons is, at all ratios, a constant as determined by the speed of the main drive.

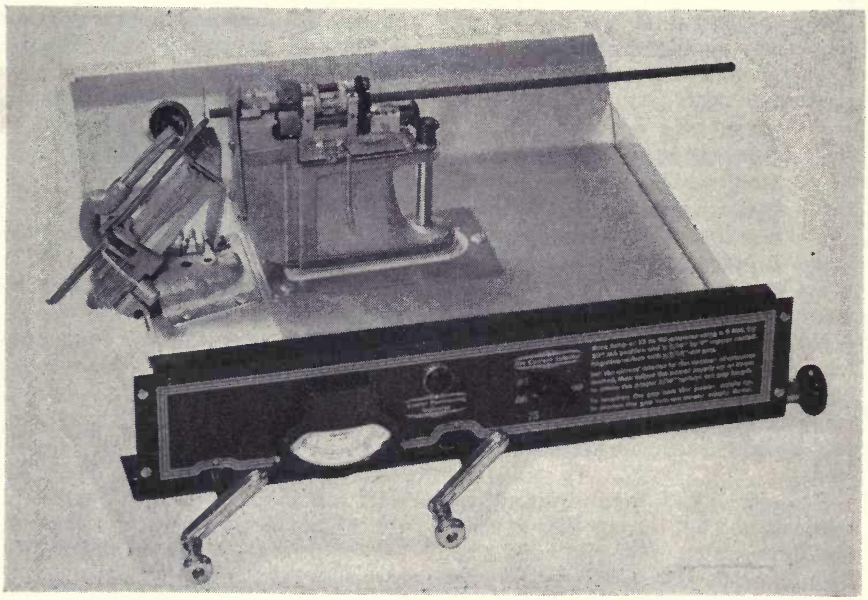


Fig. 2. General view of differential feed burner from operating side showing positive and negative feeds and the single adjustment control.

Need for Automatic Positioning

This feeding system and almost all present arc feeding systems make an assumption that there will be little or no variation in arc gap length, carbon-burning rate or power supply voltage. However, in practical experience these ideal conditions are seldom satisfied.

Variations in carbon-burning rates and ratios at a given current, of course, directly reflect a change of position of the arc with respect to the lamphouse optical system. Arc-gap lengths at identical currents and even with constant applied arc voltage will vary from trim to trim and even within a trim. With constant arc current, the dependent variable that compensates for variation in arc supply voltage is the arc-gap length. As the positive carbon has the highest burning rate (being approximately 2 to 8 times that of the negative carbon), the major adjustment in position for variations in arc-gap length occurs in the position of the positive carbon. Thus, variations of arc voltage or gap length directly affect the position of the positive crater in relation to the optical system.

Therefore, to adopt the ideal carbon-feed system to these practical considerations, there must be introduced an element that will maintain the positive crater at the optical focal point regardless of variation in arc gap or burning rate.

It is, therefore, practical to introduce a carbon crater position-detecting and ratio control-actuating mechanism into this system to accomplish this end. The

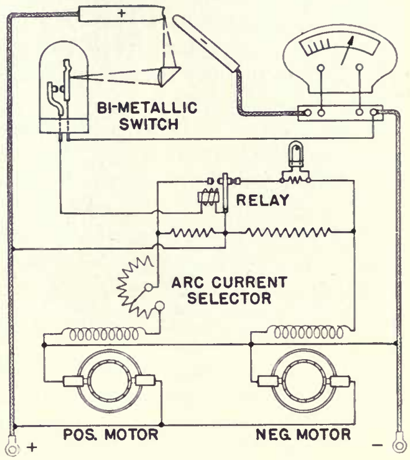


Fig. 3. Simplified arc control circuit diagram.

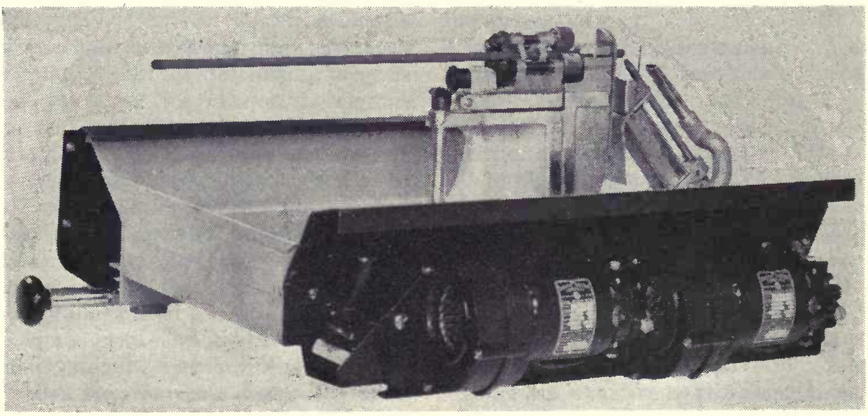


Fig. 4. General view of burner from nonoperating side showing motors and bimetallic switch behind left motor.

bimetallic element with its ruggedness and simplicity seems to be most practical for this position detector.[3]

This bimetal switch is simply arranged to shunt out a series resistance in the ratio-motor field circuit. With all resistance shunted out, the ratio motor runs at a speed such that the negative carbon is fed at a rate below its burning rate, and the positive is fed at a rate above its burning rate. When the resistance is inserted by action of the bimetal switch, the negative is fed at a rate above, and the positive at a rate below its burning rate.

Total rate of feed at any selected amperage is obtained from the main-drive motor, and the position of the positive carbon is accurately maintained with the controlled variation of the ratio motor.

Angle-Trim Lamp-Feed Considerations

With the use of angle-trim lamps, the general considerations for constant illumination remain the same with the exception that to maintain this even illumination, the feed rate of the negative has to be corrected for its angular direction before it can be added to the positive to obtain the value for combined total feed.

It has been confirmed by experiment that, within a reasonable limit of movement, if the positive carbon is underfed a certain amount, X, an overfeed of the negative equal in amount to X cosine α will maintain constant arc current, where α is the depression angle of the negative in relation to the positive.

Taking advantage of the uniform and predictable speed characteristics of the d-c shunt motor, it is possible to design an electrical differential motor feed circuit whereby the use of the mechanical differential is eliminated. With this arrangement, each carbon is driven by a separate motor. Such a system, without an automatic position-control switch, would contain two controls, each consisting of two rheostats connected in mechanical tandem. Each of the rheostats in the total feed-rate control would be connected in the field circuit of its respective motor, and the resistance values arranged so that the carbon-feed speeds were changed approximately in their correct values throughout the entire current range of the carbons.

The ratio-control rheostats would be connected in the two-motor field circuits in such a manner that as the ratio control was advanced, the positive feed motor would be slowed and the negative feed motor would be speeded the correct amount to maintain the same current in the lamphouse.

For automatic positioning, the bimetallic element would be arranged to shunt in and out portions of this ratio-control rheostat. The general optical arrangement for projecting the energy image of the positive carbon and flame to the bimetallic switch is shown in Fig. 1. The 90° prism with a lens ground in one face is used to direct the side view of the arc to the glass-enclosed bimetallic switch.

Single-Feed Control

It is possible to obtain d-c shunt motors with speed characteristics such that as the arc voltage is raised, consistent with higher arc currents, the negative feed motor will increase in speed approximately the right amount to compensate for the increased negative burning rate.

This fact, in conjunction with the use of a fairly large speed differential on both motors, controlled by means of the position-sensitive device, has enabled considerable simplification of the control circuit.

The net result has been the development of a circuit in which complete control of both carbon feeds throughout their entire amperage range has been accomplished with but a single lamphouse feed-control adjustment. This control is in the form of a single rheo-

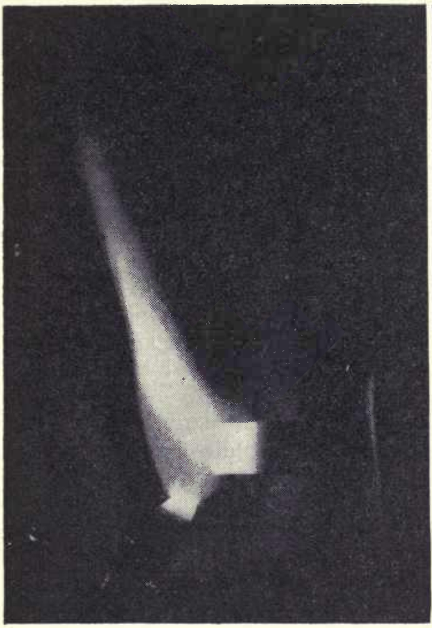


Fig. 5. (a) The arc burning with no air supplied from jet showing the characteristic long-tail flame reaching toward the optical system.

Fig. 5. (b) The burning arc showing how the application of air from the jet shortens and redirects the flame.

stat which is provided with a pointer and a scale indicating arc amperages. The general arrangement of components of a burner incorporating this two-motor, single-control feed system as viewed from the operating side is shown in Fig. 2. A simplified wiring diagram of this system is shown in Fig. 3.

The rheostat is connected in the positive feed motor field circuit and has a value sufficient to control the feed of the positive carbon through a range of from 14 to 32 in./hr.

The bimetallic switch is connected in such a manner that in its open position, a resistor is inserted in the positive field, and a resistance is shunted out in the negative field, thus speeding the positive and simultaneously slowing the negative. When the bimetallic switch is closed by reason of the positive carbon position being slightly too near the optical system, the resistor in the positive field circuit is shunted, and the resistor is simultaneously inserted in the negative field circuit, thus slowing the positive and speeding the negative.

The positive motor will change speed sufficiently with this cycling to change the feed rate by approximately 4 in./hr from fast to slow rate. With the negative carbon being depressed at an angle of 52°, its feed rate is arranged to change 4 × cos 52°, or approximately 2.5 in./hr from fast to slow.

When the arc current selector rheostat is set at the desired current, the positive motor assumes a speed, such that the average speed between high-

and low-cycle speeds is equal to the average burning rate of the positive carbon at the selected current.

If the arc current at a particular instant is slightly less than the selected current, the positive burning rate will be slightly lower than the average positive feed rate. Consequently, the arc position-control switch will remain in the low-speed positive feed position longer at a time, than in the high-speed positive feed position. This will cause the negative to be fed at a greater average rate than it is being consumed, thereby shortening the arc gap, and raising the current, until an equilibrium condition is reached, at which the average negative and positive burning rates equal the average feed rates. This will be realized at approximately a 50% division of time on high and low speeds.

If the arc current, and consequently the positive burning rate is higher than the selected rate, the arc position-control switch will remain in the high-speed position longer at a time than in the low-speed position. This will cause the negative to be fed at a lower than average rate, thereby lengthening the arc gap until equilibrium is reached.

Slow changes in power supply voltage are compensated for by the automatic resulting change in arc-gap length, but with the continual maintenance of the positive crater at the required position.

Miscellaneous Features

Secondary considerations in connection with the realization of the two-motor automatic positioning drive include the provision of centrifugal fans on each of the motors (see Fig. 4). These fans exhaust into the burner base enclosure from where the air is directed up through the rotating positive feed head, and against the negative feed head, thereby keeping these parts at low operating temperatures.

Immediately above and parallel to the negative carbon is located a jet tube which directs a stream of air at the arc tail flame immediately above the crater.

This device has several useful functions in that it shortens and redirects the tail flame away from the reflector, as shown in Fig. 5. The white ash product of combustion of the arc is blown away from the reflector thereby eliminating deposit on the reflector and the consequent breakage caused by heat differentials.

Another benefit derived from the air jet is that it supplies enough additional air to the vicinity of the arc that upon striking the arc, the soot particles are consumed instead of being released to the reflector surface, or lamp-house interior.

Finally, the air jet causes the blending of the negative and positive flames and results in excellent stabilization of the arc without the use of an auxiliary magnetic field. Thus, with the embodiment of the differential concept of carbon feed which was developed for the purpose of obtaining uniform feed in conjunction with automatic positioning of the positive crater, it is possible to stabilize the burning of the arc and keep the products of combustion from the lamphouse optical system.

References

1. D. B. Joy and E. R. Geib, "The non-rotating high-intensity d-c arc for projection," *Jour. SMPE*, vol. 24, pp. 47–62, Jan. 1935.
2. "Report of the Projection Practice Committee," *Jour. SMPE*, vol. 24, pp. 35–46, Jan. 1935.
3. D. J. Zaffarano, W. W. Lozier and D. B. Joy, "Improved methods of controlling carbon arc position," *Jour. SMPE*, vol. 37, pp. 485–501, Nov. 1941.

Bibliography on High-Speed Photography

Including Schlieren and Cathode-Ray Oscillograph Photography

Contents

This bibliography was compiled by Miss Elsie Garvin, Librarian, Research Library, Eastman Kodak Co., Rochester, N.Y., and was recommended for publication in the *Journal* by the Society's High-Speed Photography Committee. Those who reviewed the 600 items suggested that they be arranged by subject and that certain entries be expanded by annotation. John H. Waddell, Chairman of the Committee, undertook the job of classification; many more items were added, dating up to July, 1950; and manuscript was released on December 7, 1950, for publication.

The Society has previously published two reprint volumes on high-speed photography and this bibliography will be the last item in Vol. 3 which will include also those papers on the subject which appeared in the *Journal* during 1950.

To expand its usefulness the third volume will include a cumulative table of contents showing the titles and authors of all papers in Vols. 1 through 3. It will cover all articles on the subject which appeared in the *Journal* beginning with the special issue, Part II of the March, 1949, *Journal.*

I. GENERAL

L'Ultra-cinéma, P. Nogùes, *Cinémat. franç.*, *9:* 29–32, Apr. 30, 1927.

Der Zeitdehner, sein Bau und seine Anwendung, R. Thun, *Kinotechnik, 10:* 119–26, Mar. 5, 1928. (*General discussion of instruments working between limits of 100–1,000,000 per sec.*)

Rapidkameras, *Lichtbildbühne, 21:* 16–19, Nov. 3, 1928. (*Historical.*)

Kinematographie auf ruhendem Film und mit extrem hoher Bildfrequenz, C. Cranz and H. Schardin, *Zeit. Physik, 56:* 147–83, #3/4, 1929. (*1/10 to 1/3 millionth of a sec.*)

Theorie der Thunschen Zeitdehners und ihre Anwendung in der Augnahmepraxis, W. Ende, *Zeit. tech. Physik, 11:* 394–402, #10, 1930.

Première Essais de Cinématographie Ultra-rapide, A. Magnan, Hermann et Cie, Paris, 1932. (*History.*)

Kinematographische und photographische Untersuchungsmethoden schnell verlaufender Vergänge, F. Beck. *Ber. Int. Kong. Phot. Dresden, 1931*, 261–65, 1932.

High-Speed Motion Pictures, H. E. Edgerton, *Elec. Eng., 54:* 149–53, Feb. 1935.

Speed Photography, *New Photo-Miniature* (old series #206), New series #1, 1–32, 1935.

High-Speed Photography, H. E. Edgerton, K. J. Germeshausen and H. E. Grier, *Phot. J., 76:* 198–204, Apr. 1936.

Sound Waves—Their Shape and Sound, D. C. Miller, Macmillan, New York, 1937. (*Contains a chapter on Electric-Spark Photography of Sound Waves.*)

Entwicklung der Hochfrequenzkinematographie, F. E. von Eckard, *Filmtechnik, 13:* 121–23, July 6, 1937.

High-Speed Photographic Methods of Measurement, H. E. Edgerton, K. J. Germeshausen and H. E. Grier, *J. Appl. Phys., 8:* 2–9, Jan. 1937.

Flash! Seeing the Unseen by Ultra High-speed Photography, H. E. Edgerton and J. R. Killian, Jr., Hale, Cushman and Flint, Boston, 1939. (*Bibliography.*)

Tampering with Time, Gjon Mili, *Photo Technique, 1:* 4–9, Aug. 1939.

Action Photography, G. Denes, Fountain Press, London, 1940.

Photographische Messtechnik, L. Fink, R. Oldenbourg, Munchen, 1940.

Photographing Action, V. De Palma, Ziff-Davis, Chicago 1940.

High-Speed Photography, C. Tuttle and F. Brown, *Complete Photog., 5:* 1965–68, Issue 30, 1942; *6:* 1969–74, Issue 31. 1942.

High-Speed Flash Photography, H. L. Westrate, *Intern. Phot., 14:* 4–5, Sept. 1942.

Photographic Analysis of Motion, E. R. Davies, *Nature, 152:* 261–64, Sept. 4, 1943.

High-Speed Photography. A Monograph, L. Wells, *Australasian Photo-Rev., 51:* 317–23. 25, Oct. 1944.

Photography in Engineering, C. H. Tupholme, Faber and Hyperion Ltd., London, 1945. (*Chapter called "High-Speed Photography,"* pp. 99–131.)

The Scientist in Wartime, E. Appleton, *Engineer, 180:* 432–33, Nov. 30, 1945.

Speed Camera. The Amateur Photography of Motor Racing, E. S. Tompkins, G. T. Foulis, London, 1946.

High-Speed Motion Picture Photography, H. M. Lester, *J. Biol. Phot. Assoc., 14:* 107–18, Mar. 1946.

High-Speed Photography, (Alpha Photo Lab), *The Cinema:* 45, Apr. 3, 1946.

Photographic Aspects of High-Speed Recording, W. F. Berg, *Phot. J., 86B:* 154–58, Nov. 1946.

Flash in Modern Photography, William Mortensen and D. M. Paul, Camera Craft, San Francisco, 1947.

Flash Photography, Gordon Parks, Franklin Watts, New York, 1947.

Synchronized Flashlight Photography, G. L. Wakefield and N. W. Smith, Fountain Press, London, 2nd ed., 1947.

Symposium on High-Speed Photography, *Brit. J. Phot., 94:* 44, Jan. 24, 1947.

The Past, Present and Future of High-Speed Photography, H. E. Edgerton, *PSA Jour., 13:* 437–38, July 1947.

Graphic Graflex Photography, Willard D. Morgan and H. M. Lester, Morgan and Lester, New York, 8th ed., 1948.

Le cinéma scientifique française, P. Thévenard and G. Rassel, *La Jeune Parque*, Paris, 1948. (*Étude analytique des mouvements rapides, pp. 3–39; historical, high-speed and very high-speed.*)

"Strobe" the Lively Light, H. Luray, Camera Craft, San Francisco, 1949.

What is High-Speed Photography, M. L. Sandell, *Jour. SMPE, 52:* 5–7, Mar. Pt. 2, 1949.

A Photographic Study of Rapid Events, W. D. Chesterman. (*Book in preparation for Oxford University Press.*)

Photographic Instantanée et Cinématographie Ultra-Rapide, P. Fayolle and P. Naslin, Editions de la Revue d'Optique, Paris, 1950.

A Survey of High-Speed Motion Picture Photography, K. Shaftan, *Jour. SMPTE, 54:* 603–26, May 1950.

II. CAMERAS

1,000,000 Pictures per Minute, C. F. Jenkins, *Trans. SMPE, No. 13:* 69–73, 1921.

Analysis of Motion, C. P. Watson, *Trans. SMPE, No. 13:* 65–58, 1921. (*Novograph high-speed motion picture camera. 125–160 pictures per sec.*)

Motion Picture Camera Taking 3,200 Pictures per Second, C. F. Jenkins, *Trans. SMPE, No. 17:* 77–78, 1923.

The Heape and Grylls Camera, C. N. Bennett, *Kinemat. Weekly, 87:* 76, May 15, 1924.

A Camera for Studying Projectiles in Flight, H. L. Curtis, W. H. Wadleigh and A. H. Sellman, *Tech. Papers Bur. Stand.*, #255, *18:* 189–202, 1924.

Die Lyta-Spiegelreflex-Kamera mit Hochfrequenzeinrichtung, O. C. Tauern, *Kinotechnisches Jahrbuch*, 55–59, 1925–26.

The Jenkins Chronoteine Camera for High-Speed Motion Studies, C. Jenkins, *Trans. SMPE., 10:* 25–30, #25, May 1926.

The Heape and Grylls' Machine for High-Speed Photography, W. H. Connell, *J. Sci. Instr., 4:* 82–87, Dec. 1926.

Askania-Hochfrequenz-Modell 27, H. Friess *Filmtechnik, 3:* 62–64, Feb. 19, 1927.

Der Thun'sche Zeitdehner. Model NSOKT 3, A. v. Barsy, *Kinotechnik, 9:* 348–52, July 5, 1927.

Appareil à grande vitesse Gaumont pour prise de vues cinématographiques, Établisements Gaumont, *Bull. soc. franç. phot.*, (3) *14:* 204–7, July 1927.

A Novel High-Speed Camera, E. B. Wedmore, *J. Sci. Instr., 4:* 345–47, Aug. 1927. (*A variation of Heape and Grylls' high-speed camera.*)

Ein Report-Apparat, *Filmtechnik 3:* 314–15, Aug. 20, 1927. (*Gaumont camera, 150 exposures per sec., works forward or backward.*)

Fin Rapidkamera vom Jahre 1897, A. Lassally, *Kinotechnik, 9:* 588–95, Nov. 20, 1927. (*100 pictures per sec.*)

Die Anwendung des Zeitdehners beim Studium von Kavitations-erscheinungen, H. Mueller, *Kinotechnik, 10:* 462–65, Sept. 5, 1928. (*75,000 exposures per sec.*)

A New Ultra-Speed Kinematographic Camera Taking 40,000 Photographs per Second, T. Suhara, *Proc. Imperial Acad. Japan, 5:* 334, Oct. 1929.

Der Thun'sche Zeitdehner des Institutes für Kleinzeitforschung, *Kinotechnik, 11:* 145–47, Mar. 20, 1929. (*Thun's camera, 8 to 10 meters of film per sec. or 4000 pictures per sec. with exposures as short as 1/75,000 per sec.*)

The Fearless High-Speed Camera Movement, *Intern. Phot., 1:* 41, Oct. 1929.

Die Neue Zeitlupe, H. Joachim, *Filmtechnik, 6:* 10, Jan. 11, 1930. (*Zeiss Ikon improvement of old Ernemann camera.*)

Photographing Sound, C. Neblette, *Photo Era, 64:* 160–63, #3, 1930. (*Foley's apparatus for spark photography is illustrated.*)

New Ultra-Speed Kinematographic Camera Taking 40,000 Photographs per Second, T. Suhara, N. Sato and S. Kamei, *Report of the Tokyo University Aeronaut. Research Inst.*, #60, May 1930. (*Translated by P. Schrott from above as: Eine neue Hochfrequenz-Kino-Kamera für 40,000 Bilder je Sekunde. Kinotechnik, 12: 495–97, Sept. 20, 1930.*)

Electrooptical Shutter—Its Theory and Technique, F. G. Dunnington, *Phys. Rev., 38:* 1506–34, Oct. 15, 1931.

High-Frequency Camera for the Study of Electrical Discharges, *Photo Era, 67:* 102, Aug. 1931. (*Twenty-two matched lenses focused on an 8 × 11 in. plate or cut film holder. Finally arranged for stereoscopic effects.*)

Moreno-Snyder Camera Makes High Speed for Trick Shot, *Amer. Cinemat., 12:* 43, Sept. 1931. (*1440 feet per minute with non-intermittent camera.*)

Latest Newman-Sinclair Auto-Kine Models, *Kinemat. Weekly, 178:* 38–39, Dec. 17, 1931. (*10 to 24 frames per sec.*)

Cinématographie jusqu'a 12,000 Vues per Second, A. Magnan, Hermann et Cie, Paris, 1932.

Stroboscopic and Slow-Motion Pictures by Means of Intermittent Light, H. E. Edgerton, *Jour. SMPE, 18:* 356–64, Mar. 1932.

The Problem of Motion Picture Projection from Continuously Moving Film, F. E. Tuttle and C. D. Reid, *Jour. SMPE, 20:* 3–30, Jan. 1933.

Théodolite cinématographique à grande vitesse Debrie, *Rev. d'Optique, 12:* 222–25, May 1933.

A Non-Intermittent High-Speed 16-mm Camera, F. E. Tuttle, *Jour. SMPE, 21:* 474–77, Dec. 1933.

Stroboscopic Light High-Speed Motion Pictures, H. E. Edgerton and K. J. Germeshausen, *Jour. SMPE, 23:* 284–98, Nov. 1934; *Trans. Amer. Inst. Chem. Eng., 30:* 420–37, 1934.

Zeiss Ikon High-Frequency Camera, *Brit. J. Phot., 82:* 617–18, Sept. 27, 1935.

Über den Verdampfungsvorgang nach kinematographischen Aufnahmen an Dampfblasen, W. Fritz and W. Ende, *Physik, Zeit. 37:* 391–401, #11, 1936. (*Modification of Thun's high-speed camera; process of evaporation shown by cinematograph pictures of bubbles of steam.*)

Le cinéma scientifique en France et ses réalisations techniques, P. Michaut, *Tech. cinémat., 8:* 757–58, Oct. 1936. (*J. Painleve's stop-motion picture camera for color cinematography.*)

100 Bilder/Sek. mit Achterfilm!, *Film für Alle, 10:* 140–41, May 1936. (*The new Cine-Nizo 8ZD 8-mm camera taking up to 100 frames per sec.*)

Photographic "Judge" at the Olympic Games, *Brit. J. Phot., 83:* 688–89, Oct. 30, 1936. (*Zeiss-Ikon duplicate stereocinematograph apparatus.*)

Photographic Race-Timing Equipment, F. E. Tuttle and C. H. Green, *Jour. SMPE, 27:* 529–36, Nov. 1936.

Studying High-Speed Operations: New Camera to Take 2,000 Exposures a Second, *Ind. Eng. Chem. News ed., 14:* 474, Dec. 10, 1936. (*Motion picture camera with quartz lenses.*)

A Rotating Drum Camera for Photographing Transient Phenomena, R. Lambert, *Rev. Sci. Instr., 8:* 13–15, Jan. 1937.

Drum Camera for Recording Transient Electrical Phenomena, F. E. Lutrin, *J. Sci. Instr., 14:* 209–12, June 1937.

Six Thousand Images a Second Can Be Taken with This Camera, *Photography, 5:* 47, Feb. 1937. (*8-Mm motion picture camera developed in France by Merlin and Gerin built to take 6000 images per sec.*)

Der Zeitdehner der Technik für 80,000 bis 16 Aufnahmen in der Sekunde, *Phot. Ind., 35:* 391–94, Mar. 31, 1937. (*German A.E.G. camera 16 to 80,000 images per sec.*)

High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus, W. Herriott, *Jour. SMPE, 30:* 30–37, Jan. 1938.

8-Mm. Ultra-Rapid Camera, *Kinemat. Weekly, 262:* 36, Dec. 15, 1938. (*Merlin Gerin's camera.*)

Vinten High-Speed Camera, D. H. Geary, *Phot. J., 79:* 291–92, Apr. 1939.

Der neue Askania Zeitraffer, A. Jotzoff, *Kinotechnik, 22:* 15–17, Feb. 1940; cf. Askania bringt neuen Universal Zeitraffer, H. Linke, *Filmtechnik, 16:* 61–62, May/June 1940.

A 120,000 Exposure-per-Second Camera, D. C. Prince and W. K. Rankin, *Gen. Elec. Rev., 42:* 391–93, Sept. 1939.

Cameras for Lightning Studies, C. J. Kettler, *Photo Technique, 2:* 38–43, May 1940.

A Concise Report on a High-Speed Camera for Simultaneous Photographic and Oscillographic Records, H. W. Baxter, *J. Sci. Instr., 19:* 183–84, Dec. 1942.

Fastax: Ultra-High-Speed Motion Picture Camera, H. J. Smith, *Bell Lab. Record, 22:* 1–4, Sept. 1943.

Study of High Explosives by High-Speed Photography, R. W. Cairns, *Ind. Eng. Chem., 36:* 79–85, Jan. 1944.

High-Speed Cinematograph Camera, P. S. H. Henry, *J. Sci. Instr., 21:* 135–41, Aug. 1944.

The Eastman High-Speed Camera, Type III, J. L. Boon, *Jour. SMPE, 43:* 321–26, Nov. 1944.

High-Speed Cameras, E. D. Eyles, *J. Brit. Kinemat. Soc., 7:* 84–91, July-Sept. 1944; *Amer. Cinemat., 25:* 372–73, 380, 392, Nov. 1944.

The Ribbon-Frame Camera (High-Speed Still Camera), F. Reck, *Bell Lab. Record, 23:* 40–45, Feb. 1945.

Sur un cinématographie rapide pour pellicule de 9 mm de large donnant de 1500 à 2000 images par seconde, A. Magnan, *Compt. rend., 200:* 804–5, Mar. 4, 1945.

New Photoelectric-Grid Shutter Perfects Night Aerial Photography, *Phot. Trade News, 9:* 28–29, May 1945. (*1/500 sec.*)

The High-Speed Motion Picture Camera, H. J. Smith, *Commercial Phot., 20:* 248–51, May; 281–84, 285, June 1945.

8000 Pictures per Second, H. J. Smith, *Jour. SMPE, 45:* 171–83, Sept. 1945.

Two-Channel Ballistics Camera, N. E. Alexander, *Office of Technical Services,* P.B. L 58,200, Dec. 1945.

Robatron Camera, A. Busch, *Pop. Phot., 18:* 110, 112, #2, Feb. 1946.

A Wide-Angle 35-Mm High-Speed Motion-Picture Camera, J. H. Waddell, *Jour. SMPE, 46:* 87–102, Feb. 1946; cf. *Bell Lab. Record, 24:* 139–44, Apr. 1946.

The Scophony High-Speed Camera, *Phot. J., 86B:* 42–46, #2, Mar.–Apr. 1946.

High-Speed Camera, K. M. Baird, *Can. J. Research, 24A:* 41–45, July 1946.

Wartime Camera Turns Civilian, M. Royer, *Pop. Phot., 19:* 82, 84, July 1946. (*Fairchild K-25 Sequence camera.*)

High-Speed Camera, C. D. Miller, *Mech. Eng., 68:* 903, Oct. 1946.

Optical Problems of the Image Formation in High-Speed Motion Picture Cameras, J. Kudar, *Jour. SMPE, 47:* 400–2, Nov. 1946.

Pictures of the Invisible—New Machine Takes Super-Speed Photos, *U. S. Camera, 9:* 32, #10, Nov. 1946.

Fastax High-Speed Camera: 4000 Pictures a Second, *Amer. Cinemat., 28:* 7,22, Jan. 1947.

New 16-Mm Professional Camera, F. F. Baker, *Jour. SMPE, 48:* 157–61, Feb. 1947.

The Marley High-Speed Camera, R. H. Bomback, *Photography* (New Series), *2:* 28, 32, May–June 1947.

Photography at Five Million Frames per Second, B. O'Brien, *Elec. Eng., 67:* 157, Feb. 1948.

U. S. Navy Magnified Time: Special High-Speed Cameras, *Product Eng., 19:* 147–48, Aug. 1948; cf. *Electronics, 21:* 164–66, July 1948. (*Zarem camera, 400,000 frames per sec.*)

40,000 Frames per Second, C. D. Miller, *PSA Jour., 14:* 669–74, Nov. 1948. (*Detailed illustrations of the camera.*)

Child Photography, the Modern Way, J. Schneider, *The Camera Mag.*, Baltimore, Md., 1949.

Motion Picture Photography at Ten Million Frames per Second, B. O'Brien and G. Milne, *Jour. SMPE, 52:* 30–41, Jan. 1949.

Motion Picture Equipment for Very High-Speed Photography, B. O'Brien and G. G. Milne, *Jour. SMPE, 52:* 42–48, Mar. Pt. 2, 1949.

Lenses for High-Speed Motion Picture Cameras, A. A. Cook, *Jour. SMPE, 52:* 110–15, Mar. Pt. 2, 1949.

The Research Camera Greatly Extends Man's Vision. 288,000 Frames a Minute, *Phot. Age, 4:* 15–16, 19, June 1949.

New High-Speed Camera, *International Phot., 21:* 18–19, Aug. 1949.

High-Speed Recording by a Rotating-Mirror Method, J. D. Owen and R. M. Davies, *Nature, 164:* 752, Oct. 29, 1949.

High-Speed Motion Pictures by Multiple-Aperture Focal-Plane Scanners, F. E. Tuttle, *Jour. SMPE, 53:* 451–61, Nov. 1949.

Improvements in High-Speed Motion Pictures by Multiple-Aperture Focal-Plane Scanners, F. E. Tuttle, *Jour. SMPE, 53:* 462–68, Nov. 1949.

Twenty-Lens High-Speed Camera, C. W. Wyckoff, *Jour. SMPE, 53:* 469–78, Nov. 1949.

Half-Million Stationary Images per Second With Refocused Revolving Beams, C. D. Miller, *Jour. SMPE, 53:* 479–88, Nov. 1949.

Very High-Speed Drum-Type Camera, K. M. Baird and D. S. L. Durie, *Jour. SMPE, 53:* 489–95, Nov. 1949.

Design of Rotating Prisms for High-Speed Cameras, J. H. Waddell, *Jour. SMPE, 53:* 496–501, Nov. 1949.

Bowen Ribbon-Frame Camera, E. E. Green and T. J. Obst, *Jour. SMPE, 53:* 515–23, Nov. 1949.

Race Finish Recorder, J. C. Beckman and E. M. Whitley, *Electronics, 22:* 98–100, Dec. 1949.

High-Speed Synchroscope, G. G. Kelley, *Rev. Sci. Instr., 21:* 71–76, Jan. 1950.

Hand-Held High Speed Motion Picture Camera, B. Marcus, *Photographic Engineering, 1:* 57–62, Apr. 1950.

Streak Photography, I. Vigness and R. C. Nowak, *J. Appl. Phys., 21:* 445–48, May 1950.

A 100,000,000 Frame per Second Camera, M. Sultanoff, *Rev. Sci. Instr., 21:* 653, July 1950.

III. LIGHTING

Sur la cinématographie ultrarapide, H. Abraham, E. Bloch and L. Bloch, *Compt. rend., 169:* 1031–33, Dec. 1, 1919. (*Bull's oscillating spark light source.*)

Lighting for Color Photography, Gjon Mili, *J. Phot. Soc. Amer., 4:* 11–13, Summer 1938.

Speedlamp, M. L. Sandell, *Complete Phot., 9:* 3281–88, Issue 51, 1943.

10-Millionths-Second Exposures Used to Photograph Water Spray, *Phot. Trade News, 7:* 19, Mar. 1943; cf. *Westinghouse Eng., 3:* 50, May 1943. (*1/10,000,000 of a sec. high-intensity flash from a 5500-v spark gap.*)

Four-Microsecond Flash Unit, *Electronics, 16:* 144, 146, Oct. 1943.

Photoflash Lamps—Motion Pictures, H. M. Lester, *Gen. Elec. Rev., 47:* 19–20, Apr. 1944.

Continuous Flash Lighting—An Improved High-Intensity Light Source for High-Speed Motion Picture Photography, H. M. Lester, *Jour. SMPE, 45:* 358–69, Nov. 1945.

Speedlights, A. Palme, Amer. Phot. Publ. Co., Boston, 1946.

Light Source for High-Speed Photography, Gen. Radio Co., *Electronics, 19:* 302, Jan. 1946.

Speedlight and Photoflash, A. Palme, *Amer. Phot., 40:* 28–29, July 1946.

Continuous-Flash Illumination for High-Speed Motion Picture Photography, H. M. Lester, *J. Phot. Soc. Amer., 12:* 623–29, Nov. 1946.

Continuous Flash Illumination for High-Speed Motion Picture Photography, H. M. Lester, *Phot. Age, 2:* 22–26, 39, Jan. 1947.

Characteristics and Application of Flash-tubes, F. E. Carlson and D. A. Pritchard, *Illuminating Eng., 42:* 235–48, Feb. 1947.

Flashtubes—A Potential Illuminant for Motion-Picture Photography, F. E. Carlson, *Jour. SMPE, 48:* 395–406, May 1947.

Spark Light-Source of Short Duration, J. W. Beams, A. R. Kuhlthau, A. C. Lapsley, J. H. McQueen, L. B. Snoddy and W. D. Whitehead, Jr., *J. Opt. Soc. Amer., 37:* 868–70, Oct. 1947.

Discharge Lamps for Photography and Projection, H. K. Bourne, Chapman, London, 1948.

The High Intensity Flash-Discharge Tube, J. N. Aldington, *Endeavour, 7:* 21–26, Jan. 1948.

Microflash Unit for Ballistic Photography, W. W. McCormick, L. Madansky and A. F. Fairbanks, *J. Appl. Phys., 19:* 221–25, Mar. 1948.

High-Speed Flash Unit, A. J. Drugan, *U. S. Camera, 11:* 22–23, June 1948.

The Flash-tube and Its Applications, J. N. Aldington and A. J. Meadowcroft, *J. Inst. Elec. Eng., 95:* 671–81, Part 2, Dec. 1948.

Characteristic of Photoflash Lamps, M. P. Murgal, *J. Sci. Ind. Res., 8:* 44–50, Feb. 1949.

Lamps for High-Speed Photography, R. E. Farnham, *Jour. SMPE, 52:* 35–51, Mar. Pt. 2, 1949.

New High-Speed Stroboscope for High-Speed Motion Pictures, K. J. Germeshausen, *Jour. SMPE, 52:* 24–34, Mar. Pt. 2, 1949.

High-Speed Flash for Black and White and Color, H. G. Morse, *PSA Jour., 15:* 242–44, Apr. 1949.

G. E. Develops Powerful Photo Lamp for High-Speed Film Production, *Business Screen Mag., 10:* 44, #2, Apr. 1949.

High-Intensity Flash-Tubes, G. Knott, *Phot. J., 89B:* 46–50, May-June 1949.

High-Speed Flash Tubes and Their Applications, A. J. Meadowcroft, *Phot. J., 89B:* 51–53, May-June 1949.

A High-Intensity Light Source for High-Speed Kinematography, E. J. G. Beeson, *Phot. J., 89B:* 62–67, May-June 1949; cf. *Nature, 164:* 453–54, Sept. 10, 1949.

New Lighting for High-Speed Photography, W. R. Plant, *Gen. Elec. Rev., 52:* 22–27, June 1949; cf. *Phot. Age, 4:* 10–11, 22–23, Sept. 1949; 8–10, Oct. 1949.

Tracer Lights, *Modern Photography, 13:* 44–47, 126–27, Oct. 1949.

Cine-Flash Equipment for High-Speed Cinephotography, H. K. Bourne, *Functional Photography, 1:* 17–19, Jan. 1950.

The Stroboscope as a Light Source for Motion Pictures, R. S. Carlson and H. E. Edgerton, *Jour. SMPTE, 55:* 88–100, July 1950.

IV. OSCILLOGRAPHY

Improved Cathode-Ray Tube Method of the Harmonic Comparison of Frequency, D. W. Dye, *Proc. Phys. Soc.* (London), *37:* 158–68, Apr. 1925.

A Photokymographic Method with Continuous Cathode Ray Oscillograms, W. S. McCulloch and G. R. Wendt, *Science, 83:* 354–55, Apr. 10, 1936.

New Siemens and Halske Cathode Ray Oscillograph, W. Gaarz and P. P. Klein, *Siemens Rev., 13:* 138–48, #4, 1937.

Über Kathodenstrahlphotographie, W. Holzer, *Phot. Korr., 73:* 9–14, Jan. 1937.

A Film Camera for Use with the Cathode-Ray Oscillograph, Specially Designed for Experiments on Artificial Radioactivity, L. G. Grimmett and W. H. Rann, *J. Sci. Instr., 14:* 96–100, Mar. 1937.

The Recording of Rapidly Occurring Electric Phenomena With the Aid of the Cathode-Ray Tube and the Camera, J. F. H. Custers, *Philips Tech. Rev., 2:* 148–55, May 1937.

Nachbeschleunigungs—Elektronstrahl Oszillograph, A. Bigalke, *Zeit. tech. Physik, 19:* 163–66, #6, 1938.

Oscillograph Film Camera for Brief Records, A. J. Small, *J. Sci. Instr., 15:* 238–39, 1938.

Schaltvorrichtung für Aufnahmen kurzzeitiger elektrischer Vorgänge mit dem Siemens-Schliefen Ozillographen, W. Neumann, *Zeit. Instrumentenkunde, 58:* 41–43, Jan. 1938.

A Recurrent Surge Oscillograph, G. J. Scoles, *J. Sci. Instr.*, *15:* 201-5, June 1938.

An Apparatus for the Measurement of Scanning Speeds of Cathode-Ray Tubes, L. Blok, *Philips Tech. Rev.*, *3:* 216–19, July 1938. (*Apparatus is described for the determination of the greatest scanning speed of cathode-ray tubes which can be photographed.*)

Use of High-Vacuum Cathode-Ray Tube for Recording High-Speed Transient Phenomena, D. I. McGillewie, *J. Inst. Elec. Eng.*, *83:* 657–80, Nov. 1938; *Elec. Communication*, *17:* 124–32, Oct. 1938.

Principles et construction des oscillographes à rayons cathodiques, M. Demontvignier, *Rev. gén. eléc.*, *45:* 3–14, Jan. 7, 1939; 38–42, Jan. 14, 1939.

Oscillographe cathodique simple pour l'enrégistrement de phénomènes transitoires, J. Cuilhe and T. Vogel, *Rev. gén. eléc.*, *45:* 103–6, Jan. 28, 1939.

The Testing of Electric Fuses with the Cathode-Ray Oscillograph, J. A. M. Liempt and J. A. deVriend, *Philips Tech. Rev.*, *4:* 118–20, Apr. 1939.

Cathode-Ray Screen Photography, *Electronics*, *11:* 37–38, Apr. 1939.

Cathode-Ray Tube Photography, T. A. Rogers and B. L. Robertson, *Electronics*, *12:* 19, July 1939.

A Cathode-Ray Oscillograph, J. D. Veegens, *Philips Tech. Rev.*, *4:* 198–204, July 1939. (*Possibility of observing or photographing single phenomena of short duration is discussed.*)

Cathode-Ray Photography, J. H. Jupe, *Wireless World*, *45:* 233–34, Sept. 7, 1939. (*Choice of films and plates, exposure, aperture and reduction of image, formulas for developers.*)

A New Oscillograph for the Testing of Shot-Firing Machines (in German), W. Härtel, *Siemens Zeit.*, 499–508, Nov. 1939. (*Oscillograph is of electromagnetic type with photographic recording on a drum driven at 1500 rpm.*)

Automatic Cathode-Ray Oscillograph, W. L. Gaines, *Bell Lab. Record*, *18:* 145–50, Jan. 1940. (*The photographic mechanism is described.*)

Testing Amplifier Output Valves by Means of the Cathode-Ray Tube, A. J. Heins van der Ven, *Philips Tech. Rev.*, *5:* 61–68, Mar. 1940.

Ueber die Beurteilung und den objektiven Vergleich der Messleistung von Kathodenstrahloszillographen, B. von Borries and E. Ruska, *Arch. für Elektrotech.*, *34:* 161–66, Mar. 1940. (*The output of a cathode-ray oscillograph as a measuring instrument is determined by the speed of the spot and the sensitivity. The speed is the maximum at which an impression can be made on a photographic plate; this speed combined with the diameter of the spot is a measure of the resolving power. The sensitivity combined with the spot diameter measures the accuracy. In practice, a compromise between the two qualities is the most satisfactory solution and certain rules are proposed.*)

A Recording System Designed for the Investigation of the Electrical Relations in the Brains of Small Animals, G. A. Woonton, *Can. J. Research*, *18A:* 65–73, Apr. 1940. (*Two RCA high-vacuum cathode-ray tubes and a motor-driven Stoppani camera were used.*)

Cathode-Ray Oscillograph for Use in Tool Making, S. L. de Bruin and C. Dorsman, *Philips Tech. Rev.*, *5:* 277–85, Oct. 1940.

A High-Voltage Cathode-Ray Oscillograph, A. C. Hall and J. M. Coombs, *Rev. Sci. Instr.*, *11:* 314–20, Oct. 1940.

Photography of Cathode-Ray Tube Traces, H. F. Folkerts and P. A. Richards, *RCA Rev.*, *6:* 234–44, Oct. 1941.

A Cathode-Ray Oscillograph with Rotating Drum Camera, E. G. Downie, *Trans. Elec. Eng.*, *60:* 984–85, Nov. 1941.

Die Verwendung von Kaltkathodenstrahloszillographen, G. Induni, *Schweiz. Arch. angew. wiss. Tech.*, *8:* 35–45, Feb. 1942. (*Examples are given of the use of single- and double-ray cold-cathode c.r. oscillographs for electron refraction investigation of molecular structure with numerous photographs.*)

Errors in Photography of Cathode-Ray Tube Traces. The Effects of Screen Curvature, H. Moss and E. Cattanes, *Electronic Eng.* *14:* 720–21, Apr. 1942.

The Production of Elastic Waves by Explosion Pressures, II., J. A. Sharpe, *Geophysics*, *7:* 311–21, July 1942. (*A cathode-ray oscilloscope was used with ultraspeed film photosensitized with mercury.*)

The Cathode-Ray Tube Used Stroboscopically, G. Bocking, *Electronic Eng.*, *15:* 102–3, Aug. 1942.

The New Fastax High-Speed Camera, C. L. Strong, *Amer. Cinemat.*, *24:* 292–93, 297, Aug. 1943; cf. H. J. Smith, *Bell Lab. Record*, *22:* 1–4, #1, Sept. 1942.

Application of Oscillograph to Determination of Cooling Rates of Quenched Steels, C. R. Austin, R. M. Allen and W. G. VanNote, *Trans. Amer. Soc. Metals*, *30:* 747–75, Sept. 1942.

Applications of Cathode-Ray Tubes, B. Dudley, *Electronics, 15:* 49–52, 154–55, Oct. 1942.

Recording Machinery Noise Characteristics, H. D. Brailsford, *Electronics, 15:* 46–51, 164–66, Nov. 1942. (*Includes description of apparatus.*)

A Concise Report on a High-Speed Camera for Simultaneous Photographic and Oscillographic Records, H. W. Baxter, *J. Sci. Instr., 19:* 183–84, Dec. 1942.

The Photography of High-Speed Transient Phenomena with the Sealed-Off Glass-Tube Cathode-Ray Oscillograph, W. Nethercot, *J. Sci. Instr., 20:* 75–78, May 1943.

Precision Stroboscopic Frequency Meter, E. L. Kent, *Electronics, 16:* 120–21, Sept. 1943.

Photography of Cathode-Ray Tube Traces, N. Hendry, *Electronic Eng., 16:* 324–26, Jan. 1944.

Photographing Patterns on Cathode-Ray Tubes, R. Feldt, *Electronics, 17:* 130–37, 262, 264, 266, Feb. 1944.

Recording High-Speed Transient Phenomena by the Hot-Cathode, Glass-Bulb, Cathode-Ray Oscillograph, W. Nethercot, *Electronic Eng., 16:* 369–71, Feb. 1944; note on above by H. Moss, p. 411, Mar. 1944.

A Continuous Film-Recording Camera for Use with Standard Cathode-Ray Oscilloscopes, A. H. Simons, *Electronic Eng., 18:* 10–12, Jan. 1946.

Chemical Propellants. The System Hydrogen Peroxide–Permanganate, F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes, J. H. Ladd and J. E. Ross, *Ind. Eng. Chem., 38:* 160–69, Feb. 1946. (*A General Motors capacitance gage cathode-ray oscillograph 35-mm camera oscillograph recorder was used to record pressure in chamber of a thrust motor.*)

High-Speed Photography of the Cathode-Ray Tube, H. Goldstein and P. D. Bales, *Rev. Sci. Instr., 17:* 89–96, Mar. 1946.

High-Speed Oscillograph, N. Rohats, *Electronics, 19:* 135–37, Apr. 1946.

The Photographic Recording of Cathode-Ray Tube Screen Traces. The Choice of Emulsions and Developers, R. J. Hercock, *Phot. J., 86B:* 138–42, Nov.-Dec. 1946.

The Photography of High-Speed Traces with the Sealed-Off Glass Cathode-Ray Tube, W. Nethercot, *Phot. J., 86B:* 159–64, Nov.-Dec. 1946.

The Photographic Recording of Cathode-Ray Tube Traces, R. J. Hercock, Ilford Ltd., London, 1947.

Photographing Cooling Curves of Hardening Oils by Means of a Cathode-Ray Oscillograph, *Philips Tech. Rev., 9:* 147–48, #5, 1947.

Cathode-Ray Tube Shutter-Testing Instrument, D. T. R. Dighton and H. McG. Ross, *J. Sci. Instr., 24:* 128–33, May 1947.

Recording Oscilloscope Images, *Tele-Tech, 6:* 45–46, Apr. 1947; cf. *Instruments, 20:* 1052, Nov. 1947.

Note on the Photography of Cathode-Ray Oscillograms, M. V. Scherb, *Rev. Sci. Instr., 18:* 925, Dec. 1947.

Multi-Channel Recording of Oscillograph Traces, *Engineer, 184:* 560, Dec. 12, 1947.

An Oscilloscope Camera, H. E. Hale and H. P. Mansberg, *Electronics, 21:* 102–7, June 1948; cf. *Instruments, 20:* 1052–53, Nov. 1947. (*1–3600 feet per minute.*)

Illumination of Cathode-Ray Oscillograph Screen for Photography, E. C. Crittenden, Jr., C. S. Smith and L. O. Olsen, *Rev. Sci. Instr., 19:* 271–72, Apr. 1948.

Continuous Oscillograph Camera for Ionosphere Measurements, J. E. Hacke, Jr., *Instruments, 21:* 914–15, Oct. 1948.

Modern Oscilloscopes and Their Uses, J. H. Ruiter, Jr., Murray Hill Books, New York, 1949.

Oscillograph for Automatic Recording of Disturbances on Electric Supply Systems, W. T. J. Atkins, *J. Inst. Elec. Eng., 95:* 276–85, Pt. 2, Apr. 1949.

Cathode-Ray-Tube Applications in Photography and Optics, C. Berkley and R. Feldt, *Jour. SMPE, 52:* 64–85, July 1949; *Electronic Eng., 21:* 114–20, Apr. 1949; 169–72, May 1949.

A Miniature Portable Cathode-Ray Oscillograph Recorder, C. F. Johnson, *Instruments, 22:* 800–1, Sept. 1949.

Techniques in High-Speed Cathode-Ray Oscillography, C. Berkley and H. P. Mansberg, *Jour. SMPE, 53:* 549–78, Nov. 1949.

Improved C-R Photographs, N. Fulmer, *Electronics, 23:* 86–87, Mar. 1950.

V. SCHLIEREN

Photography of Flying Bullets, etc., C. V. Boys, *Phot. J.*, *16:* 199–209, Apr. 30, 1892; cf. *Nature*, *47:* 415–21, Mar. 2, 1893; 440–46, Mar. 9, 1893; *Smithsonian Inst. Report for 1892–93*, 165–82.

Photography of Sound Waves by the "Schlieren Methode," R. W. Wood, *Phil. Mag.*, (5), *48:* 218–27, Aug. 1899.

Photography of Sound Waves, R. W. Wood, *Phot. J.*, *24:* 250–56, May 31, 1900.

The Photography of Sound Waves and the Demonstration of the Evolutions of Reflected Wave Fronts with the Cinematograph, R. W. Wood, *Phil. Mag.* (5), *50:* 148–56, 1900; cf. *Nature*, *62:* 342–49, Aug. 9, 1900; *Smithsonian Inst. Report for 1900*, 359 ff., 1901; *Proc. Roy Soc.*, *66:* 283–90, #429, 1900.

Movements of Flame in Explosions of Gases, H. B. Dixon, *Phil. Trans. Roy. Soc.*, *200A:* 315–52, Feb. 4, 1903.

Beobachtungen nach der Schlierenmethode, A. Toepler, W. Engelmann, Leipzig, 1906.

Photographing Air Waves and Bullets, W. Hyde, *Brit. J. Phot.*, *63:* 492–93, Sept. 8, 1916.

Über Hochfrequenz - Schlierenkinematographie und ihre Verwendung zur Untersuchung von Explosionserscheinungen und anderen sehr rasch verlaufenden Vorgängen, C. Cranz and E. Bames, *Z. angew. Chem.*, *36:* 76–80, Feb. 7, 1923.

Über Hochfrequenzschlierenphotographie, E. Bames, *Phot. Rund.*, *61:* 120–23, July 1924.

Die Photographie von Explosionsvorgängen, H. Moss, *Phot. Korr.*, *66:* 69–73, #3, 1930.

Schlieren Kinematographie, P. Schrott, *Kinotechnik*, *12:* 40–46, Jan. 1930.

Mehrfachfunkenaufnahmen von Explosionsvorgängen nach der Toeplerchen Schlierenmethode, W. Lindner, *Kinotechnik*, *12:* 356–60, July 1930.

Applications of the Schlieren Method of Photography, D. B. Gawthrop, *Rev. Sci. Instr.*, *2:* 522–31, Sept. 1931.

Ignition of Firedamp by Explosives, Study of the Process of Ignition by the Schlieren Method, W. C. F. Shepherd, *Bull. of the Bureau of Mines*, #354, 1932.

Improvements in the Schlieren Method, H. G. Taylor and J. M. Waldram, *J. Sci. Instr.*, *10:* 378–89, Dec. 1933.

Sichtbarmachung von Schwingungen einer Quarzplatte mittels der Schlierenmethode, V. Petrzilka and L. Zachoval, *Zeit. Physik*, *90:* 700–02, #9/10, 1934.

Toepler's Schlieren Method. Fundamentals of Its Application and Quantitative Use, H. Schardin, *V. D. I. Forschungsheft*, Berlin, #367, 32 pp., 1934. (*Translated by I. E. Segal, RTP Translation #249. Bibliography.*)

Improvements in the Schlieren Method of Photography, H. C. H. Townend, *J. Sci. Instr.*, *11:* 184–87, June 1934.

Die Harze der Steinkohlen, H. Winter, *Angew. Chem.*, *48:* 610–14, Sept. 21, 1935. (*Schlieren photographs indicate that fossil resins are high molecular esters.*)

Wärmubergang durch freie Konvektion an Quadratischen Platten, R. Weise, *Forsch. Gebiete Ingenieurw.*, *6:* 281–92, Nov.-Dec. 1935. (*Photographs taken by Schlieren method of temperature fields.*)

Observation of Ultracentrifugal Sedimentation by the Toepler-Schlieren Method, A. Tiselius, K. O. Pedersen and I. Eriksson-Quensel, *Nature*, *139:* 546, Mar. 27, 1937.

Measurement of Heat Transfer by Free Convection from Cylindrical Bodies by Schlieren Method, L. M. K. Boelter and V. H. Cherry, *Trans. Amer. Soc. Heating and Ventilating Engrs.*, *44:* 499–512, 1938.

Photographing the Invisible, J. H. W. Kerston, *Pop. Phot.*, *6:* 16–17, 74, 76, Apr. 1940. (*Schlieren photography.*)

Schlierenaufnahmen von Gasflammen, A. N. J. van de Poll and T. Westerdijk, *Zeit. tech. Physik*, *22:* 29–32, #2, 1941.

Schlieren and Shadowgraph Equipment for Air Flow Analysis, N. F. Barnes and S. L. Bellinger, *J. Opt. Soc. Amer.*, *35:* 497–509, Aug. 1945.

High-Speed Schlieren Camera for Observation of Flame Travel, *BIOS Report #14*, Item 9; *P. B. Report L85*, 201, 1947.

Knocking Combustion Observed in a Spark-Ignition Engine with Direct and Schlieren High-Speed Motion Pictures and Pressure Records, G. E. Osterstrom, *National Advisory Committee for Aeronautics*, Tech. note #1614, June 1948.

Electron Optical Schlieren Effect, *Tech. News Bull. Nat. Bur. Stand.*, *32:* 82–84, July 1948.

The Operation of the Puff-Ball Mechanism of Lycoperdon Perlatum by Raindrops, Shown by Ultra-High-Speed Schlieren Cinematography, P. H. Gregory, *Trans. British Mycological Soc.*, *32:* 11–15, Pt. 1, 1949.

The Application of the Schlieren Method to the Quantitative Measurement of Mixing Gases in Jets, W. R. Keagy, Jr. and H. H. Ellis, pp. 667–74, in: *Third Symposium on Combustion and Flame and Explosion Phenomena,* Williams and Wilkins, Baltimore, Md., 1949.

Visual Methods for Studying Ultrasonic Phenomena, R. B. Barnes and C. J. Burton, *J. Appl. Phys., 20:* 286–96, Apr. 1949. (*Modifications of Schlieren photography.*)

Interference Phenomenon in the Schlieren System, E. L. Gayhart and R. Prescott, *J. Opt. Soc. Amer., 39:* 546–50, July 1949.

Physical Optic Analysis of Image Quality in Schlieren Photography, H. J. Shafer, *Jour. SMPE, 53:* 524–44, Nov. 1949.

A Modified Schlieren Apparatus for Large Areas of Field, R. A. Burton, *J. Opt. Soc. Amer., 39:* 907–8, Nov. 1949.

Improved Schlieren Apparatus Employing Multiple Slit-Gratings, T. A. Mortensen, *Rev. Sci. Instr., 21:* 3–6, Jan. 1950.

VI. TECHNICAL AND TECHNIQUES

Photography of Flying Bullets, etc., C. V. Boys, *Phot. J., 16:* 199–209, Apr. 30, 1892; cf. *Nature, 47:* 415–21, Mar. 2, 1893; 440–46, Mar. 9, 1893; *Smithsonian Inst. Report for 1892–93*, 165–82.

Photography of Sound Waves, R. W. Wood, *Phot. J., 24:* 250–56, May 31, 1900.

A Study of Splashes, A. M. Worthington, Longmans, New York, 1908.

Photographing Air Waves and Bullets, W. Hyde, *Brit. J. Phot., 63:* 492–93, Sept. 8, 1916.

De la chrono-photographie par étincelle électrique à l'étude des phénoménes de ballistique, L. Bull, *Bull. rech. et inv., 1:* 48–54, Nov. 1919.

The Spectrum of Electrically Exploded Wires, J. A. Anderson, *Astrophys. J., 51:* 37–48, Jan. 1920.

Appareil pour la dissociation rapide des images dans le cinématographie par étincelle électrique, L. Bull, *Compt. rend., 174:* 1059–1061, Apr. 18, 1922.

Photography of Bullets in Flight, P. P. Quayle, *J. Franklin Inst., 193:* 627–40, May 1922.

High Speed Photography of Vibrations (Sound, Mechanical, Electrical, etc.), A. Trowbridge, *J. Franklin Inst., 194:* 713–29, Dec. 1922.

A Photographic Study of High Voltage Discharges, R. H. George, K. B. McEachron and K. A. Oplinger, *Bull. Purdue Univ. Eng. Expt. Station #19*, 118 pp., 1924.

The Movement of Flame in Closed Vessels, O. C. deC. Ellis and R. V. Wheeler, *J. Chem. Soc., 127:* 764–67, 1925.

Spark Photography and Its Application to Some Problems in Ballistics, P. P. Quayle, *Sci. Papers Bur. Stand.* #508, *20:* 237–76, 1925.

Single Spark Photography and Its Application to Some Problems in Ballistics, P. P. Quayle, *Nature, 115:* 765–70, May 16, 1925.

Spark Photography as a Means of Measuring Rate of Explosion, J. E. Smith, *Phys. Rev., 25:* 870–76, June 1925.

Tagging a Bullet on the Wing, S. P. Meek, *Sci. Amer., 81:* 158–59, Sept. 1925. (*One millionth of a second.*)

Application de la photographie sur plaque mobile à l'étude du mouvement des projectiles et en particulier à la mesure de leur vitesse, G. Foex and J. Kampé de Feriet, *Compt. rend., 181:* 597–99, Nov. 3, 1925.

General Characteristics of Electrically Exploded Wires, J. A. Anderson and S. Smith, *Astrophys. J., 64:* 295–314, Dec. 1925.

The Pressure Wave Caused by an Explosion, W. Payman and H. Robinson, *Safety in Mines Research Board Paper, #18*, 1926; W. Payman and W. C. F. Shepherd, *#29*, 1926.

Lehrbuch der Ballistik, Band 3, C. Cranz, Springer, Berlin, 1927.

Photographic Measurement of Rate of Detonation of Explosives, G. St. J. Perrott and D. B. Gawthrop, *J. Franklin Inst., 203:* 103–10, Jan. 1927; 387–406, Mar. 1927.

Flame, O. C. deC. Ellis, *Phot. J., 67:* 349–58, Aug. 1927.

Cinematographic Studies in Aerodynamics, A. Klemin, *Mech. Eng., 50:* 217–220, Mar. 1928.

Some Applications of Spark Photography, D. B. Woodbridge and A. E. Palmer, *J. Opt. Soc. Amer., 16:* 125–33, #2, 1928.

Ein neuer Trommelaufnahme—Apparat, F. Beck, *Kinotechnik, 11:* 124–26, Mar. 5, 1929; cf. *Lichtbildbühne, 22:* 18–19, Apr. 13, 1929.

Photographic Investigation of Flame Movements in Carbonic Oxide-Oxygen Explosions, W. A. Bone and R. P. Frazer, *Phil. Trans. Roy. Soc., 228:* 197–234, May 17, 1929.

Photographing Sound, C. Neblette, *Photo Era, 64:* 160–63, #3, 1930. (*Foley's apparatus for spark photography is illustrated.*)

Les ondes stationnaires ultra-sonores rendues visibles dans les gaz par la méthode des stries, E. P. Tawil, *Compt. rend., 191:* 92–95, July 16, 1930.

Application of Photography in Explosives Research, W. Payman, *Phot. J., 70:* 409–11, 419, Sept. 1930.

Méthode d'observation d'ondes sonores non stationnaires, E. P. Tawil, *Compt. rend., 191:* 998–1000, Nov. 24, 1930.

The Photography of Waves and Vortices Produced by the Discharge of an Explosive, D. B. Gawthrop, W. C. F. Shepherd and G. St. J. Perrott, *J. Franklin Inst., 211:* 67–86, Jan. 1931.

The Propagation of Flame in Electric Fields. I. Distortion of the Flame Surface, E. M. Guenault and R. V. Wheeler, *J. Chem. Soc.*, 195–99, Jan. 1931.

Explosions in Closed Cylinders. IV. Correlations of Flame Movement and Pressure Development in Methane-Air Explosions, W. A. Kirkby and R. V. Wheeler, *J. Chem. Soc.*, 847–53, Apr. 1931; V. The Effect of Restrictions, 2303–6, 1931.

Zeithehner-Untersuchungen, W. Ende, *Kinotechnik, 13:* 139–42, Apr. 20, 1931; 158–61, May 5, 1931.

Cinematographic Analysis of Mechanical Energy Expenditure in the Sprinter, C. A. Morrison and W. O. Fenn, *Jour. SMPE, 16:* 603–11, May 1931.

Sur un cinématographie ultra-rapide donnant de 2000 à 3000 images par seconde, E. Hugenard and A. Magnan, *Compt. rend., 192:* 1370–72, June 1, 1931. (*Four lenses taking 12 pictures, in area, the size of one standard 35-mm frame.*)

Die Entwicklung der Mikrokinematographie, H. Linke, *Filmtechnik, 7:* 1–4, June 27, 1931.

Explosion Waves and Shock Waves, Pt. 1. The Wave-Speed Camera and Its Application to the Photography of Bullets in Flight, W. Payman and D. W. Woodhead, *Proc. Roy. Soc., 132A:* 200–13, July 2, 1931.

Applications de la photographie stroboscopique à l'étude des moteurs à huile lourde, Clerget, *Bull. soc. franç. phot.* (3), *18:* 180–83, Sept. 1931.

Iowa Eye-movement Camera, H. H. Jasper and R. Y. Walker, *Science, 74:* 291–94, Sept. 18, 1931.

Der Lidschluss in der Zeitlupenaufnahme, H. Pander, *Kinotechnik, 13:* 366–67, Oct. 5, 1931.

Neue Ergebnisse der Hochfrequenz-Kinematographie in der technischen Forschung (mit Filmvorführung), W. Ende, *Ber. Int. Kong. Phot. Dresden*, 1931, 265–71, 1932.

Ignition of Firedamp by Explosives, Study of the Process of Ignition by the Schlieren Method, W. C. F. Shepherd, *Bull. of the Bureau of Mines*, #354, 1932.

Die Grenzen der Hochfrequenzkinematographie, H. Schardin, *Kinotechnik, 14:* 41–45, Feb. 5, 1932. (*Spark illumination is 3 million per sec.*)

The Meteorology of Gas Explosions, O. C. deC. Ellis, *Phot. J., 72:* 380–84, Sept. 1932.

New Ways of Splitting Seconds, C. H. Fetter, *Bell Telephone Quarterly, 11:* 293–300, Oct. 1932.

Propagation Tests and the Photography of the Disturbance Sent Out by the Explosion of Commercial Electric Detonators, D. B. Gawthrop, *J. Franklin Inst., 214:* 647–64, Dec. 1932.

On the Propagation of a Lightning Discharge through the Atmosphere, E. C. Halliday, *Phil. Mag.* (7), *15:* 409–20, Feb. 1933.

La cinématographie par étincelles, L. Bull, *Reunions de l'Institut d'Optique, 5:* 13–22, 1934.

Utilisation de l'étincelle électrique en balistique et en aerodynamique, L. Libesscut, *Reunions de l'Institut d'Optique, 5:* 5–12, 1934.

Photo-Record of the Speed of an Explosion Wave in an Electric Field (in English), A. E. Malijowski, B. N. Naugolnikow and K. T. Tkatschenko, *Physik. Zeit. Sowjetunion, 5:* 446–52, #3, 1934.

The Pressure Wave Sent Out by an Explosive. III. Spark Photographs With Permitted Explosives, W. Payman and D. W. Woodhead, *Safety in Mines Res. Board Paper #88*, 1934.

Determination d'eclairs rapides dans les tubes à gaz par les appareils "Stroborama," L. and A. Sequin, *Reunions de l'Institut d'Optique, 5:* 23–45, 1934.

Statistical Measurements of Turbulence in the Flow of Air through a Pipe, H. C. H. Townend, *Proc. Roy. Soc.*, *145A:* 180–211, #854, 1934.

Lightning Camera Proves Life-Saver, S. J. Cox, *Photography*, *2:* 30, Jan. 1934.

A Photoelectric Cell Method of Measuring the Velocity of Projectiles, D. C. Rose, *Can. J. Research*, *10:* 571–87, May 1934.

The Use of the Thyratron as a Light Source for Recording Purposes, D. C. Rose, *Can. J. Research*, *10:* 588–90, May 1934.

Photography of Flame in Gaseous Explosions, R. P. Fraser, *Phot. J.*, *74:* 388–405, Aug. 1934.

Speed Copes With Speed in Study of Design, F. A. Ramsdell and A. Palmer, *Machine Design*, *7:* 13–17, Mar. 1935. (*Analyzes motion of a loom.*)

New Developments in Micro Motion Picture Technic, H. Roger, *Jour. SMPE*, *24:* 475–86, June 1935.

Fortschritte auf dem Gebiet der Hochfrequenz Kinematographie, C. Cranz and H. Schardin, *Zeit. Ver. deut. Ing.*, *79:* 1075–79, Sept. 7, 1935.

Progressive Lightning, Part I, B. J. F. Schonland and H. Collens, *Proc. Roy. Soc.*, *143A:* 654–74, Feb. 1934; Part II, B. J. F. Schonland, D. J. Malan and H. Collens, *152A:* 595–625, Nov. 15, 1935.

Über den Verdampfungsvorgang nach kinematographischen Aufnahmen an Dampfblasen, W. Fritz and W. Ende, *Physik. Zeit.*, *37:* 391–401, #11, 1936. (*Modification of Thun's high speed camera; process of evaporation shown by cinematograph pictures of bubbles of steam.*)

Effect of Nozzle Design on Fuel Spray and Flame Formation in High-Speed Compression-Ignition Engine, A. M. Rothrock and C. D. Waldron, *Nat. Adv. Comm. for Aeronautics #561*, 1936.

How Does a Welding Electrode Fuse, J. Sack, *Philips Tech. Rev.*, *1:* 26–29, Jan. 1936.

Olympic Games by Stereoscopic Films, *Kinemat. Weekly*, *227:* 54, Jan. 23, 1936.

Photo-Elastic Study of Stresses Due to Impact, Z. Tuzi and M. Nisida, *Phil. Mag.* (7), *21:* 448–73, #140, Feb. (Suppl.) 1936. (*1/46,000 sec.*)

Ultra-High-Speed Motion-Picture Photography, *Ind. Eng. Chem.*, *News ed.*, *14:* 61–62, Feb. 10, 1936. (*3,000 frames per sec.*)

Nouveau dispositif cinématographique pour l'enregistrement de phénomènes très rapides, L. Bull and P. Girard, *Compt. rend.*, *202:* 554–55, #7, Feb. 17, 1936.

Nouvel appareil à plaque fixe pour l'analyse cinématographiques des mouvements rapides, L. Bull, *Bull. soc. françs. phot.* (3), *23:* 105–8, Apr. 1936.

High-Speed Motion Pictures in Industrial Development, H. I. Day, *J. Brit. Inst. Cinematography*, *4:* 15, 25, Apr. 1936.

High-Speed Motion Pictures of Engine Flames, G. M. Rassweiler and L. Withrow, *Ind. Eng. Chem.*, *28:* 672–77, June 1936.

A Method of Air Flow Cinematography Capable of Quantitative Analysis, H. C. H. Townend, *J. Aeronautical Sci.*, *3:* 343–53, Aug. 1936.

Les applications de la photographie et de la cinématographie par étincelles à l'étude des phénomènes balistiques et aerodynamiques: Photographies et cinématographies ultrarapides, P. Libessart, *Bull. soc. françs. phot.* (3), *23:* 192–204, Sept. 1936.

Photographic "Judge" at the Olympic Games, *Brit. J. Phot.*, *83:* 688–89, Oct. 30, 1936. (*Zeiss-Ikon duplicate stereocinematograph apparatus.*)

Use of Motion Pictures in an Accurate System for Timing and Judging Horse Races, H. I. Day, *Jour. SMPE*, *27:* 513–28, Nov. 1936.

Sound Wave Stroboscope, B. F. McNamee, *Electronics*, *9:* 24–26, 34, Nov. 1936.

Ultra-Slow Motion Photography as Applied to Chemical Engineering Studies, G. J. Esselen and J. G. Hildebrand, *Trans. Amer. Inst. Chem. Eng.*, *32:* 557–65, Dec. 25, 1936.

High-Speed Cameras for Measuring the Rate of Detonation in Solid Explosives, W. Payman, W. C. F. Shepherd and D. W. Woodhead, *Safety in Mines Research Board Paper #99*, 29 pp., 1937.

Welding & Welding Rods, J. Sack, *Philips Tech. Rev.*, *2:* 129–35, May 1937.

Application de la photographie à l'étude des luminosités produites par la détonation des explosifs, A. Michel-Levy, *Bull. soc. françs. phot.* (3), *24:* 125–32, July 1937.

High-Speed Camera for Propeller Research, E. L. Gayheart, *Engineer*, *164:* 23–24, July 2, 1937.

A Photographic Study of the Vacuum Spark Discharge, J. A. Chiles, Jr., *J. Appl. Phys.*, *8:* 622–26, Sept. 1937.

Studies in Drop Formation as Revealed by the High-Speed Motion Camera, H. E. Edgerton, E. A. Hauser and W. B. Tucker, *J. Phys. Chem.*, *41:* 1017–28, Oct. 1937.

Filming Operation on Blood Corpuscles, S. H. Kahn, *Photography*, *6:* 45, Oct. 1937.

Neuere Ergebnisse der Funkenkinematographie, H. Schardin and W. Struth, *Zeit. tech. Physik, 18:* 474–77, Dec. 1937.

A Photographic Study of Combustion and Knock in a Spark-Ignition Engine, A. M. Rothrock and R. C. Spencer, *National Advisory Committee for Aeronautics Report #622,* Laboratories, Langley Field, Va., 21 pp., 1938.

High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus, W. Herriott, *Jour. SMPE, 30:* 30–37, Jan. 1938.

Cinema Section: The Stroboscope and Motion Pictures, W. A. Palmer, *Camera Craft, 45:* 31–34, Jan. 1938.

Twenty Years of Development of High-Frequency Cameras, H. E. A. Joachim, *Jour. SMPE, 30:* 169–80, Feb. 1938.

Direct Photography of Ultracentrifuge Sedimentation Curves, J. St. L. Philpot, *Nature, 141:* 283–84, Feb. 12, 1938.

Back-Projection for Amateur Studios, R. H, Alder, *Amat. Cine World, 4:* 607–8, 629. Mar. 1938.

Seeing the Unseen, R. M. Horn, *Mech. Eng., 60:* 199–201, Mar. 1938.

Adapt Your Movie Camera for Speed Stills, S. A. Pearl, *Pop. Phot., 2:* 35, 87–88, Mar. 1938.

Photomicrography of Moving Objects by Electronic Photoflash Technique, S. H. Webster, E. J. Liljegren and D. J. Zimmer, *J. Biol. Phot. Assoc., 16:* 99–102, Mar. 1938.

Photographic Study of the Motion of Fibers and Water in Flowing Fiber Suspensions, L. A. Moss and E. O. Bryant, *Paper Trade J., 106:* 46–57, Apr. 14, 1938.

Arc Studies with High-Speed Camera, Suits, *J. Appl. Phys., 9:* 188–89, Mar. 1938; cf. *Brit. J. Phot., 85:* 362, June 10, 1938.

Studying Engine Combustion by Physical Methods, L. Withrow and G. M. Rassweiler, *J. Appl. Phys., 9:* 362–72, June 1938.

Tension-Impact Testing, D. S. Clark and G. Dätwyler, *Mech. Eng., 60:* 559, July 1938.

It's a Photographic Finish, H. C. Grantz, *Cinema Digest, 4:* 8, 13, July 1938.

Hochfrequenz-Kinematographie und Funkenphotographie als Prüfmethoden bei der Wassenfabrikation, Geissler, *Filmtechnik, 14:* 206–7, Dec. 1938.

The Photography of Airscrew Sound Waves, W. F. Hilton, *Proc. Roy. Soc., 169A:* 174–90, #937, Dec. 22, 1938. (*Modified form of spark photography.*)

High-Frequency Photography and Aircraft Design, *Brit. J. Phot., 85:* 809, Dec. 23, 1938. (*Film made by A. Lippisch projected before Roy. Aeronautical Soc. showing air-flow forms. 1000 frames per sec.*)

A Study of Air Movement through Axial-Flow Free-Air Propellers, M. F. Dowell, *Gen. Elec. Rev., 42:* 210–17, 1939.

Direkte photographische Aufnahme von Elektrophorese-Diagrammen, H. Svensson, *Koll. Zeit., 87:* 181–86, #2, 1939.

Overhead Welding, J. Sack, *Philips Tech. Rev., 4:* 9–15, Jan. 1939.

Super-Super Speed, N. Taylor, *Minicam, 2:* 58–59, Jan. 1939. (*Golf pictures at 1/100,000th, 1/100th and 1/600th sec. intervals.*)

Elektronen-Vierstrahlroehre hoher Schreibgeschwindigkeit, A. Bigalke, *Arch. für Elektrotech., 33:* 108–18, Feb. 15, 1939, (*The maximum photographic recording speed is 1000 km/sec.*)

The Flashing Stroboscope, *J. Sci. Instr., 15:* 398, Dec. 1938; *Brit. J. Phot., 86:* 252, Apr. 21, 1939.

The Testing of Electric Fuses with the Cathode-Ray Oscillograph, J. A. M. Liempt and J. A. deVriend, *Philips Tech. Rev., 4:* 118–20, Apr. 1939.

Electrophoresis of Proteins by the Tiselius Method, L. G. Longsworth and D. A. MacInnes, *J. Phys. Chem., 24:* 271–81, Apr. 1939.

High-Speed Cinematography in Post Office Engineering, R. W. Palmer, *J. Brit. Kinemat. Soc., 2:* 119–24, Apr. 1939. (*Solution of problems in telephone engineering.*)

Photographische Flugleistungsmessungen, *Phot. Ind., 37:* 639–41, May 24, 1939.

Physics of Flames and Explosions of Gases, B. Lewis and G. von Elbe, *J. Appl. Phys., 10:* 344–59, June 1939.

Glass Fracture Velocity, F. E. Barstow and H. E. Edgerton, *J. Amer. Ceramic Soc. 22:* 302–7, Sept. 1939.

Engine Flame Researches, T. A. Boyd, *J. Soc. Automotive Engr., 45:* 421–32, Oct. 1939.

Multiflash Photography, H. E. Edgerton, K. J. Germeshausen and H. E. Grier, *Photo Technique, 1:* 14–16, #5, Oct. 1939.

Jets gazeux à vitesse supersonique et luminosités de détonation, H. Muraour, *Chimie et industrie, 42:* 604–6, Oct. 1939.

Super Stroboscope, Kern & Co., Ltd., *J. Sci. Instr., 16:* 381–82, Dec. 1939.

Photographische Untersuchungen an Flammen, W. Jost, *Zeit. angew. Phot.*, *2:* 1–8, #1/2, 1940. (*Method for these high-speed photographs.*)

Modern Synchroflash Photography, W. D. Morgan, *Amer. Ann. Phot.*, *54:* 203–18, 1940. (*Details on lamp and synchronizers.*)

Recording Transient Disturbances, O. D. Grismore, *Bell Lab. Record*, *18:* 140–44, Jan. 1940.

High-Speed Motion Pictures of the Human Vocal Cords, D. W. Farnsworth, *Bell Lab. Record*, *18:* 203–8, Mar. 1940.

Photographing Arcs Under Water, *Product Eng.*, *11:* 136–37, Mar. 1940.

A Recording System Designed for the Investigation of the Electrical Relations in the Brains of Small Animals, G. A. Woonton, *Can. J. Research*, *18A:* 65–73, Apr. 1940. (*Two R.C.A. high-vacuum cathode-ray tubes and a motor-driven Stoppani camera were used.*)

Taken at 1/100,000 of a Second, A. King and G. Mili, *Minicam*, *3:* 18–25, May 1940. (*Edgerton "speedlite."*)

Methods of Measuring the Torque of Induction Motors, A. C. W. V. Clarke, *J. Inst. Elec. Eng.* (London), *86:* 597–600, June 1940.

High-Speed Photography and the Study of Rapid Machine Motion, V. Sepavich and A. Palmer, *Mech. Eng.*, *62:* 519–24, July 1940.

High-Speed Photography Applied to the Study of Machine Performance, E. M. Watson, *Product Eng.*, *11:* 340–43, Aug. 1940.

Photoelasticity, an Application of Polarized Light to the Study of Strains and Stresses, M. Hetenyi, *Photo Technique*, *2:* 46–49, Nov. 1940.

Measurements on Detonation in the Duchêne Apparatus, G. Broersma, *J. Aeronautical Sci.*, *8:* 62–72, Dec. 1940.

Ueber kinematographische Aufnahmen von Pfeifentönen, K. T. Kühn, *Zeit. angew. Phot.*, *2:* 92–96, #5/6, Dec. 1940.

Cinématographie des mouvements ultra-rapides, M. L. Bull, *Université de Paris*, Paris, 16 pp., 1941.

Ballistics Photography, High Speed, R. E. Evans, *Complete Phot.*, *1:* 383–87, Issue 6, 1941.

Measurement of Supersonic Absorption in Gases by Optical Methods (in Russian), F. A. Korolev, *J. Expt. & Theoret. Phys.*, *11:* 184–93, #1, 1941.

Race-Track Photofinish Photography, R. F. Mitchell, *Amer. Annual of Photography*, *55:* 183–88, 1941.

Color Pictures of Photoelastic Models by Polarized Light, G. E. Holm, *Photo Tech.*, *3:* 65–66, Jan. 1941.

The Dynamics of Sneezing-Studies by High-Speed Photography, M. W. Jennison, *Sci. Monthly*, *62:* 24–33, Jan. 1941.

Photographing Electric Arcs in Liquids, T. E. Browne, Jr., *Photo Tech.*, *3:* 52–54, Feb. 1941.

Further Studies of Glass Fracture with High-Speed Photography, H. E. Edgerton and F. E. Barstow, *J. Amer. Ceramic Soc.*, *24:* 131–37, Apr. 1941.

The Public Health Applications of High-Speed Photography, C. E. Turner, M. W. Jennison and H. E. Edgerton, *Amer. J. Public Health*, *31:* 319–24, Apr. 1941.

Stopping Motion for Design Data, K. D. Moslander, *Machine Design*, *13:* 51–54, June 1941.

Tools Seen in Slow Motion; G. E. Engineers Find High-Speed Photography Useful in Answering Questions on Chip Formation, L. T. Weller and E. M. Watson, *Amer. Machinist*, *85:* 689–92, July 1941.

Photographic Study of A. C. Arcs in Flowing Liquids, J. Slepian and T. E. Browne, Jr., *Elec. Eng.*, *60:* 823–38, Aug. 1941.

Diesel Nozzle Spray: A Procedure for Determining Discharge Characteristics, H. F. Bryan, *Automobile Eng.*, *31:* 337–40, Oct. 1941.

Aids for Analyzing High-Speed Action, E. M. Watson, *Gen. Elec. Rev.*, *44:* 549–57, Oct. 1941.

The Direct Measurement of Lightning Current, J. W. Flowers, *J. Franklin Inst.*, *232:* 425–50, Nov. 1941.

High-Speed Photography Aids in Metal-Cutting Tests, *Pop. Phot.*, *9:* 87, Nov. 1941.

High-Speed Photography and Its Application to Industrial Problems, E. D. Eyles, *J. Sci. Instr.*, *18:* 175–84, Sept. 1941; 244, Dec. 1941. Abridged in: *J. Brit. Kinemat. Soc.*, *5:* 114–27, Oct. 1942.

Study of High-Speed Photography of Combustion and Knock in a Spark-Ignition, C. D. Miller, *Report #727 of Nat. Advisory Committee for Aeronautics*, 23 pp., 1942.

Elektrophoretic and Ultracentrifugal Analysis of Hay-Fever-Producing Component of Ragweed Pollen Extract, H. A. Abramson, D. H. Moore and H. H. Gettner, *J. Phys. Chem.*, *46:* 192–203, Jan. 1942.

Visual Studies of Flow Patterns, E. A. Hauser and D. R. Dewey, *J. Phys. Chem.*, *46:* 212–13, Jan. 1942.

The Air Corps' Newest Camera Gun, R. N. Haythorne, *Amer. Cinemat., 23:* 11, 37–38, Jan. 1942.

Lip Vibrations in a Cornet Mouthpiece, D. W. Martin, *J. Acoustical Soc. Amer., 13:* 305–8, Jan. 1942.

Balancing of Locomotive Reciprocating Parts, E. S. Cox, *Engineering, 153:* 36–38, Jan. 9, 1942.

Shutters and Cutters. High-Speed Motion-Picture Photography Used in Study of Machine-Tool Cutting Edges, B. L. McKenzie, *Sci. Amer., 166:* 60–62, Feb. 1942.

A Method of Recording Low-Intensity Flashes of Light, C. Butt and R. S. Alexander, *Rev. Sci. Instr., 13:* 151–53, Apr. 1942.

"Shooting" for Keeps, C. J. Duncan, *Minicam, 5:* 64–67, May 1942.

Photographers Play with Lightning, J. W. Gillon, *J. Phot. Soc. Amer., 8:* 217–23, May 1942.

High-Speed Photographic Analysis of Metal Cutting, *Machinery* (London), *60:* 521–22, June 4, 1942.

The Production of Elastic Waves by Explosion Pressures, II., J. A. Sharpe, *Geophysics, 7:* 311–21, July 1942. (*A cathode-ray oscilloscope was used with ultraspeed film photosensitized with mercury.*)

Gun Camera Trains Pilots, *Pop. Phot., 11:* 32, 72–73, Sept. 1942.

Decay of Vibration Phenomena of Glass Bars, J. G. McCann, *J. Amer. Ceramic Soc., 26:* 409–13, Oct. 1, 1942.

The Determination of an Unknown Frequency from a Photographic Record, M. Scott, *Electronic Eng., 15:* 243, Nov. 1942.

The Photographic Analysis of Motion, E. R. Davies, *Proc. Roy. Inst. Great Britain, 32:* 384–98, Dec. 1942.

Photographic Striation Methods Applied to the Supersonic Wind Tunnel of the E. T. H., Zurich, P. de Haller, *E. T. H. Proceedings*, 44–49, #8, 1943.

Identification of Knock in NACA High-Speed Photographs of Combustion in a Spark-Ignition Engine, C. D. Miller and H. Lowell Olsen, *National Advisory Committee for Aeronautics. Report #761*, 1943.

Speedlamp, M. L. Sandell, *Complete Phot., 9:* 3281–88, Issue 51, 1943.

Applications of Photography in Shipbuilding and Engineering, F. J. Tritton, *Trans. Inst. Engineers and Shipbuilders in Scotland, 86:* 135–64, #6, 1943.

Visualizing High-Speed Action, E. M. Watson, *Business Screen Mag., 4:* 22–6, #8, 1943.

Recording Unit for Strain and Timing Functions, J. H. Meier, *Electronics, 16:* 79–83, 114, Apr. 1943.

Air Flow Visualization Opens New Avenues of Research, E. J. Saxl, *Aviation, 42:* 148–51, 325, 329, Apr. 1943.

Photographs of Sprays May Increase Gasoline Mileage, *Commercial Phot., 18:* 246, Apr. 1943. (*Camera used to determine size of drops entering engine of car.*)

Simple Time Base for a High-Speed Cine Camera, E. D. Eyles, *J. Sci. Instr., 20.* 114–15, July 1943.

Some Applications of High-Speed Photography, E. D. Eyles, *Phot. J., 83:* 261–65, July 1943.

120,000 Frames per Second, F. Luther, *Minicam Phot., 7:* 36–47, Sept. 1943.

An Inexpensive Stroboscope for High-Speed Photography, S. Silverman and W. H. Warhus, *Rev. Sci. Instr., 14:* 273–75, Sept. 1943.

Effect of High-Intensity Arcs upon 35-mm Film Projection, E. K. Carver, R. H. Talbot and H. A. Loomis, *Jour. SMPE, 41:* 69–87, July 1943; *Int. Projectionist, 18:* 10–12, Sept. 1943; 12–14, 19, Oct. 1943.

Four-Microsecond Flash Unit, *Electronics, 16:* 144, 146, Oct. 1943.

The Photographic Determination of Flame Temperatures in Closed-Vessel Explosions, A. S. Leah, *Phil. Mag.* (7), *38:* 795–803, Dec. 1943.

Technique of Stroboscopic Studies of Insect Flight, C. M. Williams, *Science, 98:* 522–24, Dec. 1943.

Examination of the Bursting Test by High-Speed Cinematography, H. A. Harrison and G. F. Underhay, *Proc. Tech. Sect. Paper Makers' Assn., 25:* 273–79, 1944.

Study of High Explosives by High-Speed Photography, R. W. Cairns, *Ind. Eng. Chem., 36:* 79–85, Jan. 1944.

Industrial Research Progress at the Armour Research Foundation 1942–43: High-Speed Photography, *Chem. Eng. News, 22:* 29, Jan. 10, 1944.

Camera Records High Speeds, A. L. Gale, *Movie Makers, 19:* 54, 76–78, Feb. 1944.

High-Speed Movement, *Aircraft Production, 6:* 125–28, Mar. 1944.

Movies of Bullets, R. H. Bailey, *Amer. Cinemat., 25:* 11, Apr. 1944. (*Aerial gun camera.*)

Cameras Synchronized with Guns Record Hits of Aerial Gunners, *Phot. Trade News, 8:* 23–24, Apr. 1944.

Rate of Rise of Water in Capillary Tubes, W. A. Rense, *J. Appl. Phys., 15:* 436–37, May 1944.

On the Destructive Action of Cavitation, M. Kornfeld and L. Suvorov, *J. Appl, Phys., 15:* 495–506, June 1944.

Photographic Study of the Retraction of Stressed Rubber, B. A. Mrowca, S. L. Dart and E. Guth, *Phys. Rev., 66:* 32–33, July 1 and 15, 1944.

Persistence of Luminosity in Air, J. J. O'Doherty, *Nature, 154:* 339, Sept. 9, 1944. (*32 frames per sec.*)

Aids for Pictorially Analyzing High-Speed Action, E. M. Watson, *Jour. SMPE, 43:* 267–88, #4, Oct. 1944.

Harnessing Time and Motion for Industrial Research, H. D. McLarty, *Iron and Steel Eng., 21:* 70–73, Dec. 1944.

Possibilites industrielles d'un laboratorie de photographie et cinématographie ultra-rapides, P. Fayolle, *Trav. et mem. du laboratorie central des ind. mech.*, 17–25, #1, 1945.

Retraction and Stress Propagation in Natural and Synthetic Gum and Tread Stocks, B. A. Mrowca, S. L. Dart and E. Guth, *J. Appl. Phys., 16:* 8–19, Jan. 1945.

Photographing the Invisible, A. M. Lavish, *Minicam Phot., 8:* 22–24, #5, Feb. 1945.

A Special Problem in Time-Microscopy, H. M. Lester, *J. Phot. Soc. Amer., 11:* 65–68, Feb. 1945.

Samuel Slater Memorial Textile Research Laboratory, E. R. Schwarz, *Textile Research J., 15:* 33–36, Feb. 1945.

Formation of Metal-Sprayed Deposits, W. E. Ballard, *Proc. Phys. Soc.* (London), *57:* 67–83, Mar. 1945.

Photography as Applied to Textile Research, C. W. Bradley, *J. Soc. Dyers and Colourists, 61:* 61–64, Mar. 1945. (*Electric spark used at Shirley Inst. Also mentions cathode-ray briefly.*)

How Does a Fly Land on the Ceiling, E. D. Eyles, *Proc. Roy. Entomolog. Soc. London, 20A:* 14–15, Pts. 1–3, Mar. 1945.

Triggering Speedlights, A. Palme, *Amer. Phot., 39:* 34–36, May 1945.

How High-Speed Photography Aids in Redesigning, W. S. Calvert and H. D. Jackes, *Machine Design, 16:* 133–38, Feb. 17, 1945; *Brit. J. Phot., 92:* 198, June 15, 1945.

High-Speed Linear Photography, E. N. Harvey and F. J. M. Sichel, *J. Cell. Comp. Physiol., 25:* 175–79, June 1945.

Modern Measurement of Projectile Speeds, T. H. Johnson, *Electronic Ind., 4:* 82–85, 170, 174, 178, 182, 186, 190, July 1945.

High-Speed Cinematography, F. C. Johansen, *J. Inst. Mech. Eng., 152:* 224–25, Sept. 1945.

The Recording of Strain by the "Parallel Resonance" Method, H. J. Beach, *Electronic Eng., 17:* 737, Oct. 1945.

Aerodynamic Performance of Small Spheres for Subsonic to High Supersonic Velocities, A. C. Charters and R. N. Thomas, *J. Aeronautical Sci., 12:* 468–76, Oct. 1945.

Cinematographic Indicator for Locomotive Engine Cylinders, G. Bohl, *Engineers' Digest, 2:* 602–4, Dec. 1945 (taken from *Rev. gen. des chemin de fer, 63:* 137–44 Nov.-Dec. 1944).

Slow-Motion Study of Injection and Combustion of Fuel in a Diesel Engine, C. D. Miller, *S. A. E. Journal, 53:* 719–35, Dec. 1945.

Photoballistic Method of Studying Very Short Bursts of Light (In Russian), V. A. Tsukerman, *Bull. Acad. Sci.* (USSR), *Dept. Sci. Tech., #6:* 863–74, 1946.

A Combined Method for Photographing Very Rapid Processes (In English), V. A. Tsukerman, *Compt. rend.* (Doklady), *acad. sci.* (USSR), *53:* 319–21, #4, 1946.

Relation between Spark-Ignition Engine Knock Detonation Waves and Autoignition as Shown by High-Speed Photography, C. D. Miller, *National Advisory Committee for Aeronautics—Wartime Report #E-238*, 1946. (*P.B. 96,955 issued in 1949.*)

Apparatus for Stroboscopic Observations, S. L. deBruin, *Philips Tech. Rev., 8:* 25–32, Jan. 1946. (*A stroboscope of an argon gas discharge lamp and electric apparatus for condenser discharges.*)

How a Bullet Shatters Glass, A. Palme, *Amer. Phot., 40:* 14–15, Jan. 1946.

Electronic Timing of Sequence Photographs, C. H. Coles, *Electronic Ind., 5:* 74–76, Feb. 1946.

Materials in Action as Seen by the High-Speed Camera, K. Rose, *Materials and Methods, 23:* 414–17, Feb. 1946.

Single-Blow Impact Test for Cast Iron, A. B. Everest, J. W. Grant and H. Morrogh, *Engineering, 161:* 117–20, Feb. 1, 1946.

Specialized Photography Applied to Engineering in the Army Air Forces, P. M. Thomas and C. H. Coles, *Jour. SMPE, 46:* 220–30, Mar. 1946. (*High-speed motion pictures, high-speed still pictures, special recording devices.*)

High-Speed Photographs of Under-Water Explosions, D. S. Senior, *Phot. J., 86B:* 25–31, Jan.–Feb. 1946; cf. *Chem. Products, 9:* 52–58, Mar.–Apr. 1946 and *Electronic Eng., 18:* 133–35, May 1946.

Initial Stages of the Explosion of Nitroglycerine, R. G. Vines and M. F. R. Mulcahy, *Nature, 157:* 626, May 11, 1946.

Photographic Uses of Electrical Discharge Flash-Tubes, H. E. Edgerton, *J. Opt. Soc. Amer., 36:* 390–99, July 1946.

"—And Here Are the Pictures That Show It!" (Rifle Recoil after Shot Is Fired), C. H. Hopkins, *Phot. Age, 1:* 16–17, #1, July 1946.

You Can Advance Your Industrial Research and Production with High-Speed Motion Pictures, *Phot. Age. 1:* 34–37, 58, July 1946.

Instrument for Investigating the Operation of Camera Shutters, D. R. Dighton and H. M. Ross, *Phot. J., 86B:* 110–16, Sept.–Oct. 1946.

Fastax at Bikini, J. H. Waddell, *Bell Lab. Record, 24:* 358–62, Oct. 1946.

Greatest Photographic Organization in History. Shot Bikini Blast, G. Warrenton, *Amer. Cinemat., 27:* 352, 383, Oct. 1946.

Measuring Temperatures by Photography, J. H. Hall, *Phot. Trade Bull., 7:* 619, Oct. 1946. (*Exposures of 1.3 milliseconds revealed formations in steel.*)

How the Atom-Bomb Tests Were Photographed (Operation Crossroads), H. L. Hansen and D. P. Schiedt, *U. S. Camera, 9:* 16–19, 42, 48, Oct. 1946.

Action—in a Split Second, *U. S. Camera, 9:* 15, Nov. 1946. (*Hockey games. Lighting mentioned.*)

Roles of Detonation Waves and Autoignition in Spark Ignition Engine Knock as Shown by Photographs Taken at 40,000 and 200,000 Frames per Second, C. D. Miller, *Trans. Soc. Automotive Eng., 1:* 98–143, Jan. 1947; abridged in *J. Soc. Automotive Eng., 54:* 34–35, Oct. 1946.

Photographic Analysis of Performance, G. A. Jones, *Phot. J., 87B:* 7–12, Jan.–Feb. 1947.

Proceedings of the Thirteenth Annual Meeting (of the Amer. Soc. of Photogrammetry: Photography at Operation Crossroads), P. T. Cullen, *Photogrammetric Eng., 13:* 95–100, Mar. 1947.

Spread around the Initiating Point of the Detonation Wave in High Explosives, *Nature, 159:* 402, Mar. 22, 1947.

Cathode-Ray Tube Shutter-Testing Instrument, D. T. R. Dighton and H. McG. Ross, *J. Sci. Instr., 24:* 128–33, May 1947.

The Shadowgraph Recording Method, D. L. Supernaw, *Instruments, 20:* 532–35, June 1947.

Special Cameras and Flash Lamps for High-Speed Underwater Photography, R. T. Knapp, *Jour. SMPE, 49:* 64–82, July 1947.

Photography in Engine Research, H. D. Goulding, *Aircraft Production, 9:* 283–87, Aug. 1947; 338–42, Sept. 1947.

High-Speed Photography. Pt. I. External Surfaces and Opaque Objects, G. A. Hawkins and C. E. Balleisen, *Machine Design, 19:* 127–33, Aug. 1947; Pt. II. Radiography and Motion Pictures, *Machine Design, 19:* 121–26, Sept. 1947.

Measuring Pressures of Industrial Explosions, N. J. Thompson and E. W. Clusins, *Electronics, 20:* 90–93, Nov. 1947.

Velocity of Detonation of a Tubular Charge of Explosive, D. W. Woodhead, *Nature, 160:* 644, Nov. 8, 1947.

High-Speed Movie Solves Tricky Problem in Perfecting High-Pressure Hydraulic Transmission, S. G. Guins, *Machine Design, 19:* 126–28, Dec. 1947.

Underwater Explosions, R. H. Cole, Princeton University Press, Princeton, pp. 210–28, 1948. (*On photography of underwater explosions.*)

The Use of High-Speed Motion Pictures in Ordnance Research, J. E. Brock, abridgment in: *Proc. Indiana Acad. Sci., 57:* 183–85, 1948. (*Uses Fastax Camera.*)

Kinematographie und vollautomatische Serienaufnahmen schnellveränderlicher Elektroneninterferenzen, G. Möllenstedt, *Optik, 3:* 68–74, #12, 1948.

Film Solves Mystery as to How a Fly Flies, *Film World, 4:* 39, 54, Jan. 1948.

Photographic Techniques of Combustion Research, L. Beral and W. T. Cooper, *Fuel, 27:* 10–18, Jan.–Apr. 1948.

A Cinema-Spectrograph for Photographing Rapid Spectral Sequences, R. C. Herman and S. Silverman, *J. Opt. Soc. Amer., 38:* 209–11, Feb. 1948.

High-Speed Motion Pictures with Synchronized Multiflash Lighting, R. A. Anderson and W. T. Whelan, *Jour. SMPE, 50:* 109–208, Mar. 1948.

Looking at Flash, E. L. Auld, *Pop. Phot., 22:* 58–59, 164–68, Mar. 1948.

Electronic Stroboscopes, A. E. Crawford, *Aircraft Production, 10:* 101–2, Mar. 1948. (*Basic operating principles of short duration flash equipment as alternative to high-speed photography.*)

Circus Action in Color, H. E. Edgerton, *National Geographic Mag., 43:* 305–8 and plates, Mar. 1948.

Electronic Flashtube Illumination for Specialized and Motion Picture Photography, H. M. Lester, *Jour. SMPE, 50:* 208–32, Mar. 1948.

Microflash Unit for Ballistic Photography, W. W. McCormick, L. Madansky and A. F. Fairbanks, *J. Appl. Phys., 19:* 221–25, Mar. 1948.

Photography in the Study of Fibers and Textiles, C. W. Bradley, *Fibres, 9:* 45–49, 95–98, 138–41, Feb., Mar., Apr. 1948.

High-Speed Photography of Welding Arcs, F. Brailsford and K. F. Shrubb, *J. Sci. Instr., 25:* 211–13, June 1948.

Motion Picture Photography of Television Images, R. Fraser, *RCA Rev., 9:* 202–17, June 1948. (*Used to record television transmissions from cameras in aircraft and guided missiles.*)

Knocking Combustion Observed in a Spark-Ignition Engine with Direct and Schlieren High-Speed Motion Pictures and Pressure Records, G. E. Osterstrom, *National Advisory Committee for Aeronautics*, Tech. note #1614, June 1948.

Photographic Tracking of Guided Missiles, L. M. Biberman, S. E. Dorsey and D. L. Ewing, *Electronics, 21:* 92–95, July 1948.

Tracking Rockets, M. Mann, *Ordnance, 32:* 23–25, July–Aug. 1948.

High Speed Photographs of Water Jet in the End-Quench Test, R. A. Buchanan, *Metal Progress, 54:* 180–81, Aug. 1948.

Aids to Analysis of Patterns Obtained in the Diffraction of Electrons by Gases, H. J. Yearian and W. M. Barss, *J. Appl. Phys., 19:* 700–4, Aug. 1948.

Measurement of the Temperature of Sliding Surfaces with Particular Reference to Railway Brake Blocks, R. C. Parker and P. R. Marshall, *Proc. Inst. Mech. Eng., 158:* 209–29, Sept. 1948.

Highlights and Side Lights: Photographs at High Speed, *Gen. Elec. Rev., 51:* 47–48, Sept. 1948.

How the Camera Solves Tough Plant Problems, *Modern Industry, 16:* 50–53, Sept. 1948. (*General discussion on uses, lamps, etc.*)

Full Scale Free-Flight Ballistic Measurements of Guided Missiles, L. A. Delasso, L. G. DeBey and D. Reuyl, *J. Aeronautical Sci., 15:* 606–15, Oct. 1948.

High-Speed Photography, A Useful Tool, E. P. Wightman, *PSA Jour., 14:* 668, Nov. 1948.

Underwater Photographs of Flow Patterns for Surface Vessels, W. H. Sutherland, *Marine Engineering, 53:* 64–67, Oct. 1948; cf. *Mech. Eng., 70:* 1004–5, Dec. 1948.

The Flash-tube and Its Applications, J. N. Aldington and A. J. Meadowcroft, *J. Inst. Elec. Eng., 95:* 671–81, Pt. 2, Dec. 1948.

A Working Manual for Spark Shadowgraph Photography, B. S. Melton, R. Prescott and E. L. Gayhart, *Bumblebee Series, Report #90, Johns Hopkins University,* Applied Physics Laboratory, Dec. 1948.

Electronic Flash (Gas Discharge) Tube in Photography of the Anterior Segment of the Eye, R. R. Trotter and W. M. Grant, *Arch. Ophthalmology, 40:* 493–96, Nov. 1948.

The Film in Scientific Research, G. A. Jones, *British Sci. News, 2:* 235–38, #20, 1949. (*Photoelastic patterns in a railway line and chair; cylinder of combustion engine.*)

Photographs at 500,000 frames per Second of Combustion and Detonation in a Reciprocating Engine, T. Male, pp. 721–26, in: *Third Symposium on Combustion and Flame and Explosion Phenomena*, Williams & Wilkins, Baltimore, Md., 1949.

Technique for the Optical Measurement of Turbulence in High-Speed Flow, L. S. G. Kovasznay, pp. 211–222, in: *Heat Transfer and Fluid Mechanics Institute*, 1949. American Society of Mechanical Engineers, N. Y.

Use of High-Speed Photography in the Air Forces, E. A. Andres, Sr., *Jour. SMPE, 52:* 81–89, Mar. Pt. 2, 1949.

Applications of High-Speed Photography, M. Beard, *Jour. SMPE, 52:* 97–106, Mar. Pt. 2, 1949.

Control Unit for Operation of High-Speed Cameras, L. L. Neidenberg, *Jour. SMPE, 52:* 107–9, Mar. Pt. 2, 1949.

Methods of Analyzing High-Speed Photographs, W. S. Nivison, *Jour. SMPE, 52:* 49–60, Mar. Pt. 2, 1949.

High-Speed Photography in the Automotive Industry, R. O. Painter, *Jour. SMPE, 52:* 90–96, Mar. Pt. 2, 1949.

High-Speed Photographic System Using Electronic Flash Lighting, W. T. Whelan, *Jour. SMPE, 52:* 116–29, Mar. Pt. 2, 1949.

Electrical-Flash Photography, H. E. Edgerton, *Jour. SMPE, 52:* 8–23, Mar. Pt. 2, 1949.

High-Speed and Time-Lapse Photography in Industry and Research, H. M. Lester, *Jour. SMPE, 52:* 71–80, Mar. Pt. 2, 1949.

Splashes from Underwater Explosions, H. Kolsky, J. P. Lewis, M. T. Sampson, A. C. Shearman and C. I. Snow, *Proc. Roy. Soc., 196A:* 379–401, Apr. 7, 1949.

A Visual Method for Demonstrating the Path of Ultrasonic Waves through Thin Plates of Material, C. J. Burton and R. B. Barnes, *J. Appl. Phys., 20:* 462–67, May 1949. (*Photographs show reflection and transmission by metal plates.*)

Johns-Manville Research Center Uses High-Speed Photography as a Scientific Tool, Ted Czarda, *Phot. Age, 4:* 15–16, May 1949.

Film Recording of Television Transmissions for the Purpose of International Program Exchanges (in French), Y. L. Delbord, *Ann. Telecommun., 4:* 190–201, June 1949.

New Photographic Technique for Observing Velocity Fields in Water Induced by the Entry of Solid Missiles, G. Birkhoff and T. E. Caywood, *J. Appl. Phys., 20:* 646–59, July 1949.

Analyzing Equipment Operation by Photographic Measurement Techniques, S. M. Keen, *Product Eng., 20:* 119–22, July 1949.

The Recording of Optical Transients, H. A. Prime, *Proc. Inst. Elec. Eng., 96:* Pt. II: 662–70, Aug. 1949.

The Dynamics of Cavitation Bubbles, M. S. Plesset, *J. Appl. Mech., 16:* 277–82, Sept. 1949.

Auroral Radiation in the 3,000-Megacycle Region, P. A. Forsythe, W. Petrie and B. W. Currie, *Nature, 164:* 453, Sept. 10, 1949.

The Propagation of Flame. Studies of Shadow Cones and Bubble Effects, J. W. Linnett, *Chem. Age, 61:* 345, Sept. 10, 1949. (*Report of a lecture before the British Association.*)

Photographic Techniques in Combustion Research, L. Beral, *Phot. J., 89B:* 98–107, Sept.–Oct. 1949.

Repeating Flash, J. N. Aldington, *Functional Phot., 1:* 14–17, Oct. 1949. (*Used for flight of bullets and birds.*)

Shock Waves, Otto Laporte, *Sci. Amer., 181:* 14–18, #5, Nov. 1949.

Recent British Equipment and Technique for High-Speed Cinematography, G. A. Jones and E. D. Eyles, *Jour. SMPE, 53:* 502–14, Nov. 1949.

Exposure Meter for High-Speed Photography, E. T. Higgons, *Jour. SMPE, 53:* 545–48, Nov. 1949.

Measuring Shock with High-Speed Motion Pictures, J. T. Muller, *Jour. SMPE, 53:* 579–87, Nov. 1949.

High-Speed Motion Pictures in Full Color, F. M. Tylee, *Jour. SMPE, 53:* 588–93, Nov. 1949.

Light-Meter Uses with Electronic Flash, H. E. Edgerton, *PSA Jour. Pt. 2, 1:* 6–10, Jan. 1950. (*Photographic Science and Technique.*)

Flash Photolysis and Spectroscopy. A New Method for the Study of Free Radical Reactions, G. Porter, *Proc. Roy. Soc., 200A:* 284–300, Jan. 6, 1950.

Underwater Photography, J. B. Collins, *Phot. J., 90B:* 24–31, Jan.–Feb. 1950.

Measurement of Normal Burning Velocities of Propane-Air Flames from Shadow Photographs, J. W. Andersen and R. S. Fein, *J. Chem. Phys., 18:* 441–43, Apr. 1950.

High-Speed Motion Pictures in Textile Research, E. K. Fischer and J. C. Burnett, *Textile Research J., 20:* 259–69, Apr. 1950.

Motor Racing Photography, G. C. Monkhouse, *Photographic J., 90A:* 149–155, May 1950.

Streak Photography, I. Vigness and R. C. Nowak, *J. Appl. Phys., 21:* 445–48, May 1950.

The Infra-Red Photographic Evaluator, S. Horsley, *Amer. Cinemat., 31:* 196, 211–13, June 1950.

The Pressurized Ballistics Range at the Naval Ordnance Laboratory, L. P. Gieseler, *Jour. SMPTE, 55:* 53–59, July 1950.

VII. X-RAY

X-Ray Photographs with Extremely Short Exposure Times, W. J. Oosterkamp, *Philips Tech. Rev., 5:* 22–25, Jan. 1940.

Ultra-Speed Radiography, L. F. Ehrke and C. M. Slack, *Photo Technique, 3:* 53–55 Jan. 1941.

Medical Physics, O. Glasser, ed., Year Book Publishers, Inc., Chicago, 1944; *Radiography at High Speed* by C. M. Slack, pp. 1185–87.

One-Millionth-Second Radiography, C. M. Slack, *J. Phot. Soc. Amer., 11:* 302–6, Sept. 1945.

Methods of Synchronization for Very Brief X-Ray Exposures (In Russian), G. M. Strakhovskii and V. A. Tsukerman, *Bull. Acad. Sci.* (USSR), *Dept. Sci. Tech. #3:* 371–84, 1946.

One-Millionth-Second Radiography and Its Applications, C. M. Slack and D. C. Dickson, *Proc. Inst. Radio Eng., 35:* 600–6, June 1947.

A New Apparatus for Direct Cineroentgenography, A. S. Gidlund, *Acta Radiologica, 32:* 81–88, #2/3, 1949.

New Developments in X-ray Motion Pictures, C. M. Slack, L. F. Ehrke, C. T., Zavales and D. C. Dickson, *Jour. SMPE 52:* 61–70, Mar. Pt. 2, 1949.

Flash Radiography Applied to Ordnance Problems, J. C. Clark, *J. Appl. Phys., 20:* 363–70, Apr. 1949.

High-Speed Cine-Radiography, C. M. Slack, L. F. Ehrke, D. C. Dickson and C. T. Zavales, *Non-Destructive Testing, 7:* 7–11, 23, Spring 1949.

A and B Windings of 16-Mm Raw-Stock Film With Perforations Along One Edge

The Proposed American Standard for Winding of 16-Mm Sound Film, was published as a first draft in the September, 1949, Journal. While that was the first time that winding 16-mm sound film had been proposed for adoption as an American Standard, the proposals were practices already followed by the film manufacturers for a number of years. It should also be noted that, in 1941, the Society recognized the method of designating the two types of windings by publishing a Society recommendation, and that recommendation was substantially repeated in the first draft for this proposed standard.

As a result of publishing the first draft, comments were received which indicated ambiguity in the original wording; therefore, a second draft was prepared by the 16-Mm and 8-Mm Committee in January, 1950. That draft was sent to ballot of the 16-Mm and 8-Mm Committee in April, 1950. Only minor editorial comments were received and, therefore, this proposal is again being published for 90-day trial and comment (see page opposite).

It is believed this standard fills a recognized need for uniform ways of designating the direction of winding of 16-mm sound film. It is definitely not the intent of this standard to indicate any preference in the direction of winding, since existing equipments are designed to use both styles.

Revised American Standard Z22.40-1950 Sound Records and Scanning Area of 35-Mm Sound Motion Picture Prints

This standard originated as an American War Standard, Z52.36–1945. It was reapproved as American Standard, Z22.40–1946, in March, 1946 and published in the April, 1946 Journal. However, in the republishing process, a minor drafting error occurred. The arrow pointing to the outer edge of the printed area fell slightly short of the outer edge. This revised standard, Z22.40–1950, corrects that error and is thus being published now as originally intended (see p. 114).

Proposed American Standard

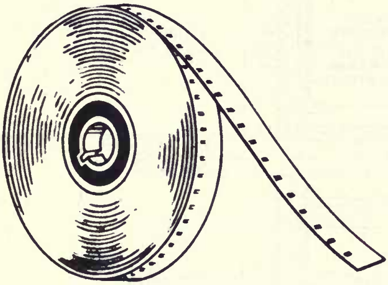
A and B Windings of 16-Mm Raw-Stock Film With Perforations Along One Edge

Z22.75

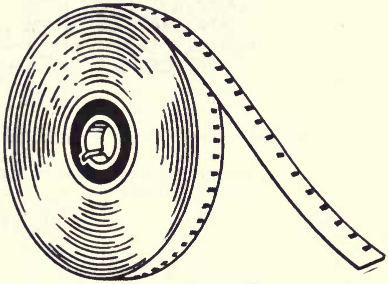
(Second Draft)

The purpose of this standard is to insure a uniform method of designating the types of winding (location of the perforated edge) in current use for 16-mm raw-stock film having perforations along one edge, thus to facilitate ordering and describing the film.

With both types of winding described below, the emulsion side of the film shall face the center of the roll.



Winding A
Emulsion side in



Winding B
Emulsion side in

When a roll of 16-mm raw stock perforated along one edge is held so that the outside end of the film leaves the roll at the top and toward the right, winding A shall have the perforations along the edge of the film toward the observer, and winding B shall have the perforations along the edge away from the observer. In either case, if the film is wound on a spool with a square hole in one flange and a round hole in the other flange, the square hole shall be on the side away from the observer.

No preference for either type of winding is implied since both types are required for use on existing equipment.

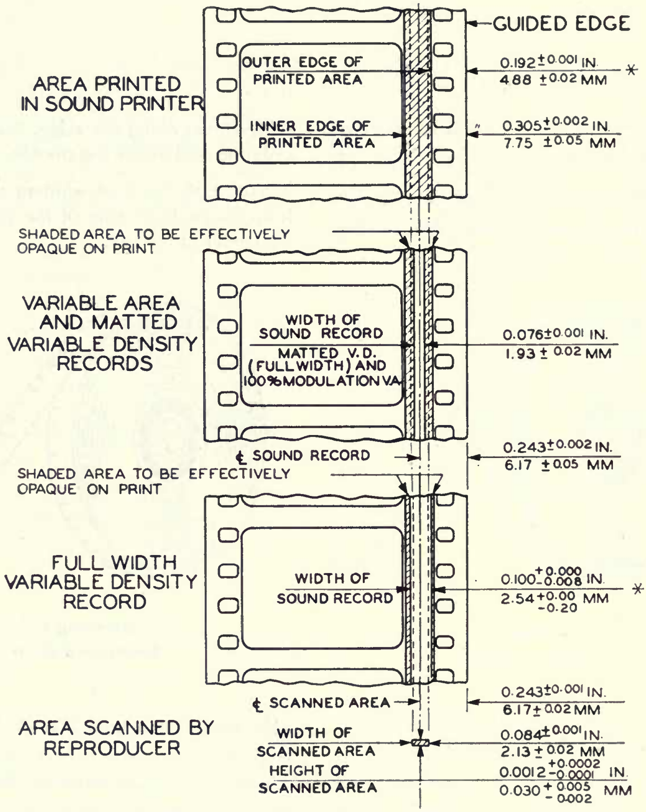
NOT APPROVED

American Standard

Dimensions and Locations for Sound Records and Scanning Area of 35-Millimeter Sound Motion Picture Prints

ASA
Reg. U. S. Pat. Off.
Z22.40-1950

Revision of
Z22.40-1946
†UDC 778.534.4



Distance Between Sound and Corresponding Picture — The sound shall precede the center of the corresponding picture by a distance of 20 ± ½ frames.

These Dimensions and Locations Are Shown Relative to Unshrunk Raw Stock.

*The only change in this standard over the 1946 edition is the correct positioning of the arrows on the dimensions marked *.

Approved October 6, 1950, by the American Standards Association, Incorporated

Sponsor: Society of Motion Picture and Television Engineers

†Universal Decimal Classification

Edge Numbering 16-Mm Motion Picture Film

THE PROPOSED American Standard for Edge Numbering 16-Mm Motion Picture Film has been under discussion for several years. In the original discussions, neither the 16-frame nor the 40-frame interval could be unanimously chosen for a standard. The laboratories producing 16-mm prints from original 35-mm material were desirous of retaining the 16-frame interval, while those working from original 16-mm film preferred 40-frame separation of the numerals. In the latter part of 1949, there was further discussion in an attempt to establish the 40-frame interval as a standard. Consequently, this proposed standard has been written to make 16-mm edge numbering optional, but specifying that the 40-frame interval is preferred.

Proposed American Standard

Edge Numbering 16-Mm Motion Picture Film

Z22.83

The purpose of this standard is to establish a uniform practice with respect to the interval between edge numbers when they are latent-image printed on 16-mm raw-stock film. It is not intended to imply that all 16-mm film should be edge-numbered.

The distance between consecutive numbers shall be 40 frames. Thus, the numbers will indicate film footage, subject to a small correction for shrinkage of the film.

NOT APPROVED

Tentative Recommendations for 16-Mm Review Rooms and Reproducing Equipment

Foreword

The tentative recommendations included herewith are the result of extensive work carried on by a Subcommittee of the 16- and 8-Mm Committee under the Chairmanship of E. W. D'Arcy. It should be clearly understood that this is not a final Society recommendation, but rather that it is an interim report of the committee. The proposal is being published at this stage to make the information available to those who have use for it and to invite additional comments and discussion.

At the outset it was agreed that the primary objective of the subcommittee was to establish a primary listening standard for gaging 16-mm print quality. This decision was reached only after lengthy discussion regarding the possibility of actually specifying the ideal over-all response characteristic of 16-mm portable projection equipment. To accomplish this end, however, appeared to be an insurmountable problem because of variation in response of the portable-type loudspeakers and the varying conditions under which the equipment is used.

The problem, therefore, was approached from the other direction, namely of trying to improve and make more uniform 16-mm release prints. It then would be left to the 16-mm projector manufacturers to adjust their equipment in any way they saw fit to best reproduce these prints.

In reaching this objective, listening tests were conducted employing various wide-range two-way speaker systems as well as portable speakers normally used with 16-mm projectors. For those listening tests a wide selection of 16-mm release material was reproduced on these systems using a number of suggested frequency characteristics.

As the testing progressed, it became more and more evident that:

First, modification of the reproducer frequency characteristics from those recommended for 35-mm theater use by the Motion Picture Research Council produced little if any significant improvement in the reproduction of 16-mm prints.

Second, if a 16-mm print reproduced well, employing the 35-mm theater systems, it also reproduced well on a conventional 16-mm projector employing small portable-type loudspeakers.

Therefore, rather than try and establish any particular electrical characteristic and portable-type speaker as a recommended review room system, it was agreed to accept those characteristics recommended for theater use, since many of the present 16-mm

Third draft, dated November 15, 1950, edited and presented for publication on January 2, 1951.

producing companies and processing laboratories already have 35-mm systems in their review rooms which can readily be modified for the 16-mm reproduction.

The frequency-response characteristics shown on the following pages are identical with those established by the Motion Picture Research Council for use in reproducing 35-mm sound films in motion picture theaters.

There are theater-type speakers not covered in these recommendations. It is hoped that suitable arrangements can be made for adding curves for these and future speakers in order that the recommendations may be as up-to-date and useful as possible.

1. *Scope*

1.1: The purpose of this standard is to facilitate the production of 16-mm films having sound tracks of high, uniform quality. It is believed that the best way to attain this objective is to establish a reference system for judging the quality of the sound from 16-mm films. Such a system requires:

(a) a sound reproducer having standardized over-all electrical frequency-response characteristics,

(b) a projector of high quality, and

(c) a review room having good acoustical properties.[1]

The characteristics established by the Motion Picture Research Council[2] for various speaker systems used in reproducing 35-mm sound film have been adopted because extensive listening tests proved them to be optimum for reproducing sound from 16-mm film also.

Thus, the electrical characteristic is specified for each particular speaker system. Before a system other than those shown below is used, it will be necessary to make comparative listening tests to determine the proper frequency-response characteristic for that system.

2. *Reproducer Requirements*

2.1: Power Output: The minimum power output of the reproducer amplifier shall be 15 w. The reproducer gain control should be calibrated in db and should indicate the gain setting required to produce 10 w output from the American Standard Signal Level Test Film Z22.45. The amplifier should have enough available gain to produce at least 20 db in excess of that required to produce 10 w.

2.2: Harmonic Distortion: The reproducer amplifier shall not introduce more than 1% harmonic distortion at 10 w output and not more than 2% at 15 w at any frequency between 50 and 7000 cycles.

2.3: Signal-to-Noise Level: The overall system noise measured electrically at the speaker terminals of the amplifier shall not be greater than 50 db. This measurement should be made with the system frequency response adjusted for the particular speaker in use and with the gain control set to deliver 10 w output when the American Standard "400 Cycle Signal Level Test Film Z22.45" is passed through the projector.

The output should be terminated in a noninductive resistive load equal to the nominal input impedance of the particular speaker system in use. The measurement should then be made without film in the gate, with the projector running and exciter lamp turned on.

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[1] "Theater acoustic recommendations of the Academy Research Council Theater Standardization Committee," *Jour. SMPE,* vol. 36, Mar. 1941.

[2] "Standard electrical characteristics for theater sound systems," *Motion Picture Research Council Bulletin,* 1948 Volume.

2.4: Frequency Response: The overall frequency-response characteristic of the projector and amplifier shall be adjusted as shown in Figs. 1 through 7, depending upon the theater speaker system to be employed. Variations are permitted from these nominal responses of ±1 db from 100 to 3000 cycles and increasing progressively with frequency to ±2 db at 7000 cycles. To adjust the system to the reverberation characteristics of a specific review room, it may also be necessary to adjust the response below 100 cycles. Variation as great as −2 db are permitted as shown on the respective curves.

These measurements shall be made with amplifier output terminated in a noninductive resistive load equal to the nominal input impedance of the particular speaker system in use. The source of signal shall be a multifre-

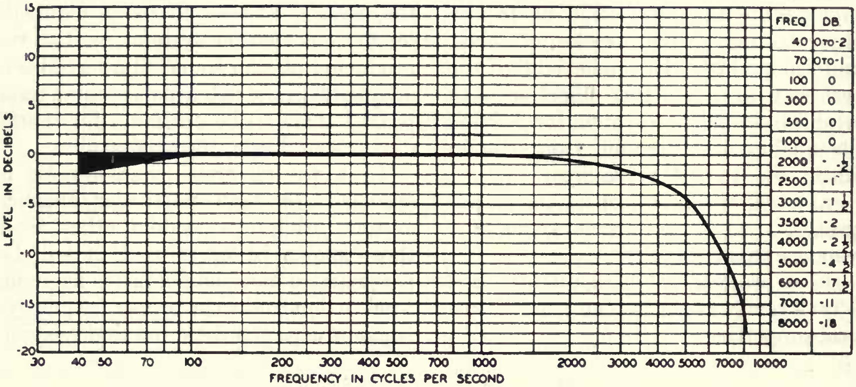

Fig. 1. Recommended electrical characteristics for 16-mm review room reproducers employing Altec Lansing Energized Loudspeaker Systems Models 75W5 and 30W5. High-frequency unit attenuation 0 to 3 db.

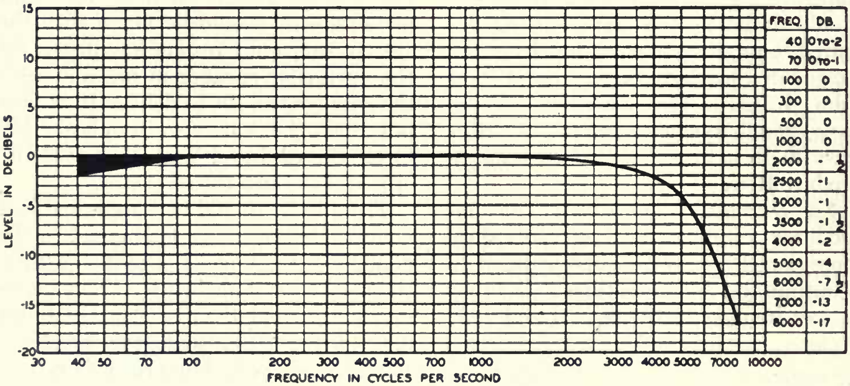

Fig. 2. Recommended electrical characteristics for 16-mm review room reproducers employing Altec Lansing Voice of the Theater Loudspeaker Systems Models A1X, A1, A2X, A2, A4X, A4 and A5. High-frequency unit attenuation 0 to 3 db.

quency test film made in accordance with American Standard Z22.44.

2.5: Uniformity of Scanning-Beam Illumination: The uniformity of scanning-beam illumination shall be such that the output from the reproducer amplifier does not vary more than $\pm 1^1/_2$ db when an American Standard Uniformity of Scanning-Beam Illumination Test Film Z22.80 is run through the reproducer.

2.6: Flutter: The flutter introduced by the reproducer shall not exceed 0.25% when using the American Standard Flutter Test Film Z22.43.

Note: This value has been selected as the maximum permissible value as measured on an RCA Flutter Bridge or on an instrument that has been adjusted to give comparable readings.

2.7: Loudspeaker Attenuation: When using the two-way loudspeakers specified in the recommendation, it is often

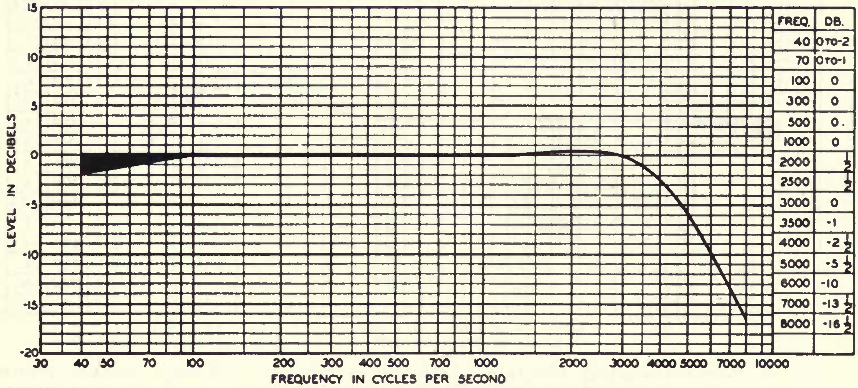

Fig. 3. Recommended electrical characteristic for 16-mm review room reproducer employing International Projector Simplex Four-Star Loudspeaker Systems Models A and B. High-frequency unit attenuation 0 to 2 db.

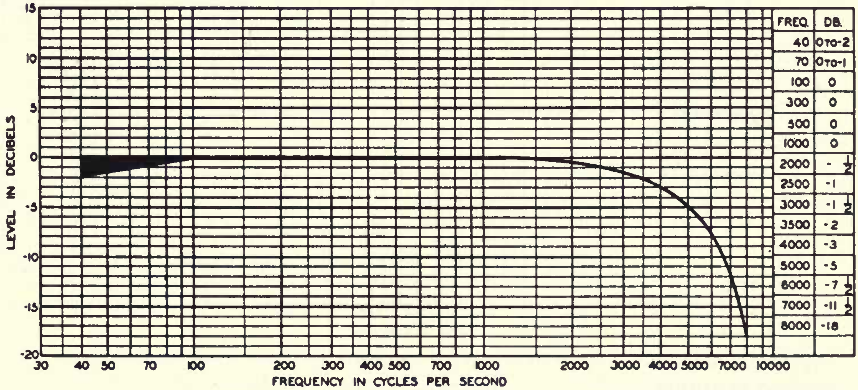

Fig. 4. Recommended electrical characteristic for 16-mm review room reproducers employing International Projector Simplex Four-Star Loudspeaker Systems Model C. High-frequency unit attenuation 2 to 3 db.

advisable to attenuate either the high- or low-frequency side of the dividing network to obtain equal acoustical response on both sides of the network cross-over frequency. Typical values of attenuation have been specified with each of the recommended response vs. frequency curves.

3. *Acoustical Requirements*

3.1: Room Reverberation Characteristics: The desirable reverberation time of a room is a function of its size. Excessive reverberation causes blurring of speech and rapidly moving staccato music. Where the reverberation time in the room is below optimum, an excessive amount of sound energy must be

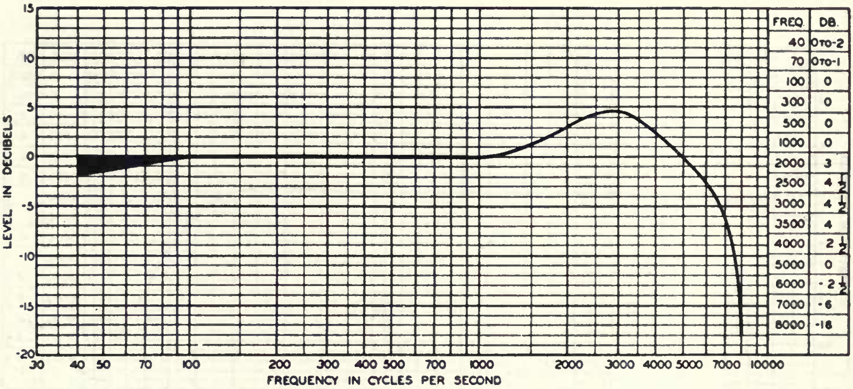

Fig. 5. Recommended electrical characteristic for 16-mm review room reproducers employing RCA Energized Loudspeaker Systems Models PG91, PG92, PG117 and PG118. Low-frequency unit attenuation 0 to 2 db.

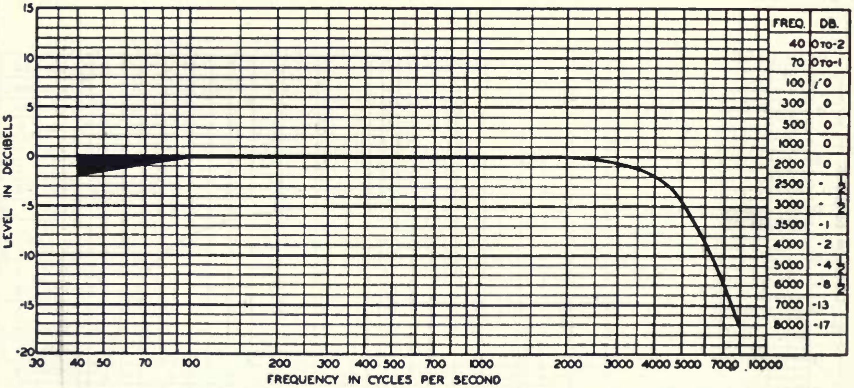

Fig. 6. Recommended electrical characteristic for 16-mm review room reproducers employing RCA Permanent Magnet Loudspeaker Systems Models PL240, PL244 and PL246. MI-9458 high-frequency unit attenuation 1 to 2 db. MI-9449 low-frequency unit attenuation 0 db. MI-9448 high-frequency unit attenuation 0 db. MI-9449 low-frequency unit attenuation 1 to 2 db.

radiated and the resultant sound is unnatural.

The optimum reverberation period varies with frequency and with the size of the room. Figure 8 gives the optimum reverberation time for theaters.

To summarize, the essential design features are:

1. A minimum volume consistent with the required seating capacity and proper auditorium proportions.

2. An auditorium width of from 50 to 70% of the length and an auditorium ceiling height of not more than 40% of the length.

3. The use of nonparallel surfaces; in particular, the floor should not be parallel to any ceiling section nor opposite side-wall sections parallel.

4. The use of convex rather than concave surfaces. In addition, the wall and ceiling surface should otherwise be broken up so as to thoroughly diffuse the sound.

5. Auditorium absorption characteristics to provide the same rate of sound

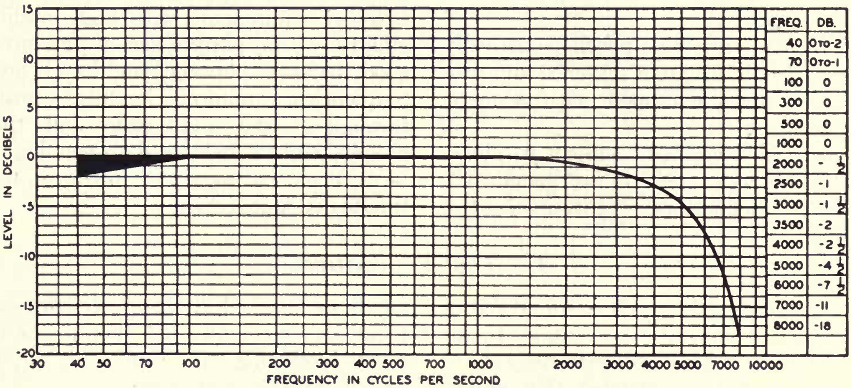

Fig. 7. Recommended electrical characteristic for 16-mm review room reproducers employing Western Electric Mirrophonic Systems Models M1, M2 and M3. High-frequency unit attenuation 2 to 4 db.

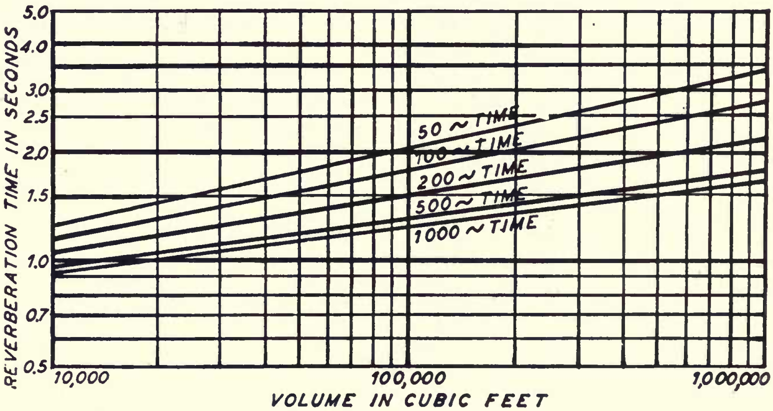

Fig. 8. Optimum reverberation time for motion picture theaters.

decay in a vertical as in a horizontal direction from side to side or from back to front walls.

6. Heavily upholstered seats and ozite-lined carpet in the aisles.

7. Backstage treatment giving a negligible amount of reflected or re-radiated sound from the backstage into the auditorium.

8. A heavily carpeted stage designed for good viewing conditions from the front seating section.

9. Auditorium walls with sufficient sound insulation material to prevent extraneous noise from entering the auditorium.

10. The projection booth acoustically treated with fireproof material and projection ports equipped with acoustic baffles.

11. All equipment subject to vibration and hum such as arc generators, voltage regulators, lighting control equipment, etc., acoustically isolated from the auditorium.

12. Air-conditioning equipment of a high-volume, low air-velocity type with air ducts provided with ascoustic baffles.

Long, narrow auditoriums, high ceilings, excessively long and narrow balcony overhangs, concave focusing surfaces, and large unbroken reflecting areas should always be avoided, as acoustical faults will always result from their use.

If these recommendations are followed, the resulting auditorium will give sound (as reproduced on a modern two-way equipment) with high intelligibility, warm, natural screen presence, good balance between high and low frequencies, uniform loudness level throughout the auditorium and the proper relative balance between high-level music passages and low-level, intimate dialogue scenes.

4. *Test Procedure*

4.1: Inasmuch as the sound-reproducing equipment in review rooms usually is subject to extremely hard usage, it is recommended that equipment purporting to meet these requirements be checked at least once a week. It is also recommended that a check sheet indicating the results of these weekly tests be maintained.

Sound Committee Report

By Lloyd T. Goldsmith, Committee Chairman

It has been several years since the Sound Committee has reported to the Society on its activities and accomplishments. It has been active, however, on projects authorized by the Engineering Vice-President and the following is an account of its work to date.

A subcommittee under the chairmanship of R. T. Van Niman investigated the possible advantages of the blue-sensitive and lead sulfide types of phototubes for 35-mm theater and 16-mm projector use over the presently used red-sensitive phototubes. This is a continuing activity being carried on with manufacturers of color films; but at the present time, only the red-sensitive phototube is recommended as giving the best all-around performance with present day black-and-white and color sound tracks. Additional data now scheduled for collection may provide the basis for modifying this statement, however.

Our committee has cooperated with a subcommittee of the 16-Mm and 8-Mm Motion Picture Committee, which is working to establish electrical characteristics for 16-mm review-room reproducers.

We studied and approved proposals which lead to the standardization of 100-mil and 200-mil push-pull sound tracks used in recording original sound.

Considerable correlation has been carried on to reconcile the Society's proposed standards of flutter definition and measurement with the proposals of Dr. Kellogg's ASA Sound Committee Z-57. Agreement has now been reached and early ASA standardization will result. The original flutter proposals were formulated by the Sound Committee under the chairmanship of J. G. Frayne, who with R. Scoville, has actively followed through with the correlation.

Our committee aided in the preparation and final approval of the Society's 16-mm Sound Service Test Film Code SPSA, which has had wide sale and use in testing the performance of 16-mm sound projectors.

The proposed British standards for magnetic recording were reviewed and comment forwarded to the British Standards Institution.

It was brought to the attention of the committee that some recent screen installations in theaters resulted in excessive loss of volume and high-frequency response from the screen horns. The committee investigated, measured the loss of screen samples, and on finding it excessive, aided the manufacturer in modifying his fabric to reduce the sound loss to accepted values. As the War Standard Z52.44-1945 "Sound Transmission of Perforated Screens" had never been reviewed and processed as an American Standard, the committee circulated it to all known screen manufacturers for approval. Their recent loss data all met the War Standard, and, accordingly, the Sound Committee approved the War Standard with minor revisions, and the new proposal was pub-

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Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y.

lished in the July, 1950, JOURNAL for a 90-day trial period leading to its eventual adoption as ASA Standard Z22.82.

The proposed American Standard for Acoustical Terminology developed by ASA Sectional Committee Z-24 on Acoustics was reviewed and suggested changes forwarded to that committee.

In May, 1948, a Subcommittee on Magnetic Recording was set up, with G. L. Dimmick as Chairman, and charged with the formulation of standard sound track dimensions and speeds of magnetic recording on 35-, 17½-, 16- and 8-mm motion picture film. With the help of several task forces assigned to specific aspects of the problem, the subcommittee prepared for the Sound Committee proposed standards which are now in the hands of the Standards Committee with the recommendation that they be published in the JOURNAL for six-month's trial and criticism. A progress report of the subcommittee was given at the 1949 Fall Convention.

The Magnetic Recording Subcommittee is about to prepare specifications for magnetic test films of the types that may be required by industry and sold by the Society. At the moment, an azimuth film, multifrequency film and buzz track appear to be most needed and will probably be made available first.

It is anticipated that problems associated with magnetic recording and reproduction will constitute the major part of the committee's work for the coming year with particular emphasis on standards, test films and television sound problems.

Theater Television Committee Report

By D. E. Hyndman, Committee Chairman

DURING 1948 AND 1949, the work of the Society's Theater Television Committee was devoted to the consideration of all engineering phases of the use of television in motion picture theaters. It reviewed the design, construction and operation of theater television equipment, from the standpoint of alterations that might be necessary within a theater, power supplies, viewing conditions, screen brightness, program distribution facilities and the like.

In June, 1949, the Federal Communications Commission requested the Society along with Paramount Pictures, Inc., and Twentieth Century-Fox Film Corp. to file a statement concerning the allocation of frequency bands for a theater television service. This request brought to an end the more or less broad general consideration that was being given to all phases of this work and forced the committee to concentrate on a statement which would outline in specific terms what the industry needed in the way of radio frequencies to establish a nation-wide theater television serv-

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Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y.

ice. On August 29, 1949, the committee filed such a statement with the Commission.

It was realized at that time that some of the conclusions reached by the statement, while based on good engineering judgment, could not be backed up by actual engineering data. It was also realized that such concrete information would have to be provided at the time of the public hearing if the industry had any hopes of having the FCC grant their request.

1950, therefore, has been devoted to securing the technical data on distribution facilities, which would substantiate the 1949 statement. As a means to this end, a subgroup was established under the chairmanship of George L. Beers of RCA. This group is composed of theater television equipment manufacturers and representatives of the common carriers. They were requested to investigate four specific characteristics of a theater television distribution system. The first dealt with the bandwidth required, the second with permissible signal-to-noise ratio, the third with distortion, and the last with the compression which could be tolerated on such a distribution system.

RCA agreed to provide the laboratory facilities for conducting these tests, provided the committee reviewed the test methods proposed and gave its assistance in interpreting the test results. At present, work is in progress on the first two of the assigned tasks, namely bandwidth and signal-to-noise. The subcommittee has approved the test methods prepared by Otto Schade and is awaiting an opportunity to judge the results on a large-screen theater system. So far, only limited viewing tests have been conducted and these on a small-screen direct-view cathode-ray tube. As soon as a large-screen laboratory setup is made available, it is hoped definite conclusions can be reached.

From the standpoint of practical operating problems, a wealth of experience will be gained from the actual theater installations that have been made in recent months. Nine theaters in seven cities now have equipment installed and are carrying weekly programs of various sports events. It is reported that before the first of the year, there will be 16 theaters so equipped. Since both cable and radio facilities are being used for program distribution to these theaters, much will be learned that will assist Mr. Beers' group in reaching rapid conclusions.

The Theater Television Committee plans to continue this activity to arrive at the answer to the basic engineering problem. When this preliminary work has been completed, it is anticipated that appropriate standards and recommendations will be set up as the Society has done in the past in the field of motion pictures.

Spring Convention 1951

APRIL 30—MAY 4 The Society's 69th Convention in 34½ years is also the 69th to be held under the able tutelage of Bill Kunzmann, Convention Vice-President. His staff of Chairmen and Vice-Chairmen for the Spring Convention have now been appointed and by the end of January will have completed the general schedule of events as well as preliminary preparation for details of the program.

NEW YORK CITY Since the Papers Committee Vice-Chairman who resides in the city where a convention is being held, automatically becomes Program Chairman, the choice of New York gives the responsibility to Bill Rivers. Among other things, he will develop the details of papers presentation along lines suggested by Ed Seeley, Papers Chairman, and will prepare manuscript copy of the Tentative and Final Programs.

HOTEL STATLER Technical Sessions will be held in the Georgian Room on the Ballroom floor of the Statler rather than in the Salle Moderne as in the past, because increased attendance has forced a move to a larger meeting room. Headquarters for the Ladies' Committee will be in Room 129 and Conference Rooms 2 or 3 on the Mezzanine have been reserved for meetings of technical committees throughout the week. The Publicity Committee will set up shop in Conference Room 8.

PAPERS Members of Ed Seeley's Papers Committee are rounding up groups of related papers on subjects that are either of special technical interest at this time or have been neglected at recent conventions. As a consequence, the program will include several symposium-type sessions, each of which will include all or nearly all convention papers related to a particular topic. Members or guests whose interests and whose time are limited will be able to derive maximum benefit from minimum participation.

ADVANCE Realistic deadline dates for printed material have been established as objectives for authors and Papers Committee members. The schedule of sessions, symposium titles, information on tours and major entertainment features must be on the editor's desk by February 19, so the Advance Notice which includes the hotel room reservation card can be printed and ready for mailing to all members on Monday, March 5.

AUTHORS By Friday, February 23, Bill Rivers must have received from each prospective author, the *white* copy of the 69th Convention Author's Form, and two copies of a 50- to 75-word abstract for use in preparing original typewritten copy of the Tentative Program. Bill also requires two self-addressed business envelopes ($4\frac{1}{4} \times 9\frac{1}{2}$ in. or thereabouts), to simplify prompt mailing of subsequent Papers Committee correspondence.

TENTATIVE Copy for the Tentative Program is scheduled to be ready for the printer on Monday, March 5. Since the convention is to be in New York, Vic Allen will arrange for printing. He expects to have the Tentative addressed to all members and in the mail, by first class, on Monday, March 26.

MANUSCRIPTS Each author must send the *buff* copy of the Author's Form with his manuscript and one full set of illustrations to Vic Allen at Society headquarters by March 23. The manuscript should be typed double-spaced on good bond paper; send the *original*, not carbon copy. Also, send Vic the original illustrations, being certain to pack them securely. Good photo-engravings cannot be made from poor reproductions of original art work.

FINAL The Final Program listing presentation times of all papers will be ready by Monday, April 23. Each author, as well as each technical session chairman and vice-chairman, will be notified of his schedule in advance so he can plan his convention week before leaving home. This is an ambitious program that calls for active support by *all* members, so give the Papers Committee and the 69th Convention Program Chairman a hand. If you are preparing a paper, please observe these deadline dates.

If you have any questions, write to Ed Seeley or Bill Rivers. Secure *Author's Forms* and *Hints to Authors* from the nearest Vice-Chairman of the

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For High-Speed Photography
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Wollensak Optical Co., 850 Hudson St., Rochester, N.Y.

As soon as the Committee's roster is complete, it will be published with the addresses of all members included.

Atlantic Coast Section Meeting

Tom H. Miller of Eastman Kodak Co., Rochester, gave an unusually interesting talk on photographic color problems before the Atlantic Coast Section in New York on December 12. A large number of colored slides were used to illustrate each point of the color problems discussed.

Mr. Miller first took up the effect of the characteristics of the light source on a color photograph. Color distribution in the source is of secondary importance in taking black-and-white pictures, partly because the finished picture must necessarily look different from the original scene. The best result is one which is pleasing to the viewer. However, a color picture must, at least in most cases, reproduce the color of the original scene as accurately as possible. But here the photographer runs into trouble due to variations in illumination of the original which may not give acceptable pictures even if perfectly reproduced by the photographic process.

The effect of different illumination of the subject was illustrated by pictures taken at midday and late afternoon of the same subject. Using film balanced for daylight (midday sunshine) the late afternoon pictures were quite obviously different and in the case of portraits less desirable, although for special effects the warmer light of late afternoon might give just the effect the photographer wants.

The speaker called attention to a variety of effects which may occur in outdoor illumination, so that the color balance may be shifted to the yellow, red or blue, depending on the subject and atmospheric conditions. Usually people do not observe these changes in illumination as accurately as the film does, because of adaptation of the eye. This was illustrated by comparison of pictures taken under outdoor and indoor illumination with the same film, showing marked difference in color balance, although an observer would have said that

the illumination was white in each case. Another characteristic of the illumination which is important in color photography is specular or diffuse reflection. In general saturated colors cannot be obtained by diffuse illumination, as for example on a cloudy or overcast day.

Mr. Miller then discussed certain characteristics of color photographing materials, particularly their inability to reproduce accurately certain colors. Most commercial materials are balanced to give good flesh tones but this does not mean that all colors will be perfectly rendered. Due to differences in processes the colors not perfectly reproduced will vary from one material to another. Consequently the only way to be sure of obtaining desired results is to make test exposures on each fabric, material and paint used in a production.

Even this is not enough since by adaptation, the eye adjusts itself to the predominant illumination and judges adjacent or subsequent colors in relation to it. This was illustrated by a series of pictures in which each varied only slightly in color balance from the preceding one. Most of them were quite acceptable although the range of color balance was very great. However, a direct change from one end of the series to the other was very noticeable and undesirable. This accounts for the fact that a color film which is satisfactory by itself may not look right when spliced between films having considerably different balance. The effect of background and surrounding illumination on apparent color rendition was also shown to be considerable.—C.R.K.

The 1951 Journal

As the Society grows, in size, occasional breaks with tradition are necessary to accommodate the diverse needs of an expanding membership. One came a year ago when "Television" was added to the Society's name, recognizing that its new importance had placed television firmly alongside motion pictures and synchronized sound. Another break occurs with the change from a single- to a two-column format beginning with this issue of the Journal.

Of several reasons for making the change at this time, two stand out: First, the amount of publishable material accepted by the Board of Editors has increased steadily for four volumes in succession, requiring the Editor to exceed his last two yearly forecasts of Journal pages to be printed. The trend will doubtless continue. Second, there has been a steady rise in cost of publication resulting from increased charges for paper, engravings and labor. None of these is likely to be reduced.

Here are two opposing factors—one highly desirable, the other inevitable—which have put the squeeze on the Society's publications program.

Under the present circumstances, two columns, with reduced margins, held the only hope for real savings. Changing the trim size by a small amount would have helped even more but seemed undesirable for the time being. Adopting a different printing method could produce no real economy because of the small press run. Any reduction in quality of the paper would have been folly, for the grade used in 1950 was about the cheapest available and often failed to yield adequate halftone illustrations.

The present format (two 13-pica columns retaining the previous typeface, Monotype 8A, set in 9-pt. on 10-pt. body) permits 37½% more information to be placed on a single 6 × 9 in. page of text. Printing and binding economies achieved in this way will just about offset certain increased charges that became effective in November, 1950, and others that start with January, 1951.

As a result, each Society dollar spent for publications in 1951 will buy as much printed information as it would have a year ago, even though costs have increased substantially during the intervening period.

Engineering Activities

Television Film Equipment

During 1950, the Society joined with the Institute of Radio Engineers and the Radio-Television Manufacturers Association (RTMA) in a cooperative program of standardization and exchange of technical data. One result was the combining of two Society Committees, the Films From Television Committee and the Television Film Projectors Committee, with similar RTMA projects, under a Television Film Equipment Committee. This joint group under the enthusiastic Chairmanship of Frank N. Gillette, General Precision Laboratory, met last October during the Convention at Lake Placid and again on January 4 in New York City.

At the recent meeting, agreement was reached on a Proposed Standard for 16-Mm Projectors for Television Film Chains Operating on Full-Storage Basis. To bring the proposal into line with the standards policies of RTMA and SMPTE, certain proprietary references were deleted and it has become largely a detailed specification for performance of the equipment. Tests, methods of measurement, references to specific test films and to particular test equipments are also included.

The Committee received favorably suggestions for area of scan on 16-mm film and for picture area in video recording. The dimensions considered with the reason for being selected will be put into the form of a Proposed American Standard. After balloting of the entire Committee, the proposals will doubtless be published in the Journal for a short period of trial and criticism.

Substantial agreement was also reached on a proposal to publish recommended standard dimensions for slides and opaques. The 2 × 2 in. transparent slide and the 4 × 5 in. opaque were considered most desirable, so the Committee will shortly vote upon them.

16-Mm and 8-Mm

The 16-Mm and 8-Mm Motion Pictures Committee, under the chairmanship of Henry Hood, has been exceptionally active. Several of the projects will soon appear in the Journal, notably the proposals on 16-mm and 8-mm film splices and on 16-mm projection reels. One project, "Recommendations for 16-Mm Review Rooms and Reproducing Equipment," developed by a subcommittee under the chairmanship of E. W. D'Arcy, appears elsewhere in this issue of the Journal. It is being published as an interim committee report in the hope that sufficient comments will be received during the ensuing year to enable the committee to formulate proposals for standardization.

Sound

At the Lake Placid Convention, the Sound Committee, under Acting Chairman, John Frayne, was faced with the urgent problem of reaching agreement on proposed standards for magnetic sound tracks on film. Protracted delay would result in incompatibility with the first equipments appearing on the market. Even more serious is the probability that the first manufacturer to produce a magnetic sound projector commercially would set the standard. With this understanding, the Committee hammered out Proposed American Standards for Magnetic Sound Track on 35- and 17½-Mm Film, 16-Mm Film, and 8-Mm Film and submitted them to the Standards Committee for its recommendations on publication for a 90-day trial. They will probably be published within the next few months.

The status of the Proposed American Standards for Sound Transmission of Theater Projection Screens published for trial in the July, 1950, Journal, was reviewed. Inasmuch as no adverse criticism had been received, it was agreed to submit it to the Standards Committee for recommendations on final approval as an American Standard.

In addition, plans were made for increasing activity on lead sulfide phototubes and standards for 16-mm magnetic film, coated full width.

BOOK REVIEWS

Fundamentals of Acoustics

By Lawrence E. Kinsler and Austin R. Frey. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. 499 pp. + 5 pp. appendix + 3 pp. glossary + 6 pp. index. 163 illus. $5\frac{1}{2} \times 8\frac{1}{2}$ in. Price $6.00.

This book presents the fundamentals underlying the generation, transmission and reception of acoustic waves. It was prepared as a textbook on the fundamentals of acoustics and is a very usable book for this purpose. The illustrations are good and each chapter is followed by a set of very well chosen problems.

The first half of the book develops the theory of vibration of solid bodies and the propagation of sound waves through fluids. It starts with simple oscillators having a single degree of freedom. In a logical manner follow chapters on the vibration of strings, bars and stretched membranes. The general acoustical wave equations for fluids are developed and applied particularly to plane and spherical waves with various boundary conditions including transmission from one medium to another. Then follows the fundamental theory of the radiation of sound from vibrating bodies of various sorts such as pistons, vibrating spheres, etc. These principles are applied to Helmholtz resonators and acoustic filters. Finally in Chapter 9 there is a brief but excellent treatise on the absorption of sound waves under various circumstances.

The theory developed in the first half of the book is applied to direct radiator loudspeakers and horn-type loudspeakers. Chapter 12 is a discussion of microphones; carbon, condenser, crystal, electrodynamic moving coil and velocity ribbon. The electroacoustical reciprocity theory is very clearly presented and applied to the calibration of these microphones.

There is a chapter on psychoacoustics dealing with the mechanism of hearing, loudness, masking, binaural localizations, etc., followed by chapters on each of the following general fields: architectural acoustics, underwater acoustics and ultrasonics.

The authors have maintained a very good balance between the fundamental aspects of the physics of the problems and the engineering applications. Numerous references are made to analogous electrical problems, but this is not overdone and each important equation is derived from the fundamental laws of physics.

It should serve as a very useful text in senior college and graduate courses, both in physics and engineering classes.—Dr. Harvey Fletcher, 5 Westminster Rd., Summit, N.J.

Fundamentals of Optics, New 2d Ed.

By Francis A. Jenkins and Harvey E. White. Published (1950) by McGraw-Hill, 330 W. 42d St., New York 18. 626 pp. + 4 pp. Answers to Problems + 17 pp. index + xi pp. 447 illus. 6×9 in. Price $7.00.

This book represents a new edition of the authors' well-known *Fundamentals of Physical Optics*, first published in 1937. As a physical optics text, it is hard to see how this book could have been improved, and it is gratifying to find that it has been reprinted almost without change in the new edition. A few sections have been added, covering the quantum nature of light and some modern developments such as the Twyman-Green interferometer, phase-contrast microscopes, interference filters, and gratings giving a 'blaze' in one order. Each topic has been treated with just the necessary degree of detail for students' use, and difficult side-issues have been carefully avoided. Having read any chapter, the reader has the pleasant feeling that now he knows all about that sub-

ject. The diagrams are clear, and the photographic illustrations excellent. A particularly gratifying feature of the treatment is that mathematics is used only to provide a deeper analysis of some physical phenomenon which has already been explained in a clear qualitative way. Too many teachers reverse this process, and feel that a mathematical treatment is the whole story. The book can be confidently recommended as an unusually clear exposition of the nature and properties of light.

The new edition also contains a lengthy section (175 pp.) on geometrical optics, which justifies the more general title. Unfortunately the method of treatment here is not nearly as good as that adopted for the physical optics part. Fermat's and Malus' theorems, and the dispersion of glass, are clearly treated, but they are actually physical optics phenomena. No less than 52 pp. are devoted to the formulas for conjugate distances and magnification, first for a thin lens, then for a single refracting surface, then again for a thick single lens, and finally for a spherical mirror. Surely it would be simpler, and more satisfying to the student, to derive the formulas for a general optical system defined by its two focal points and two principal points, and then to regard thin lenses and single surfaces as simple special cases.

It is good to find a brief reference to the photometry of optical systems and the theory of image brightness. Spectroscopic and other prisms are adequately covered. The properties of chromatic aberration are described clearly, but spherical aberration is treated in unnecessary detail. The references to coma and the sine condition suffer from the usual misunderstandings; for example, the term "sine condition" is used first to refer to the "sine theorem" (Eq. 8l, p. 121), but later it is used to refer to the difference Δf between the focal lengths of a lens for paraxial and marginal rays (Fig. 9K). The word "coma" is correctly used as a transverse measure of an aberration pattern in Fig. 9I(b), but in Figs. 9K and 9L, and in Table 9III, the same term is used to represent the longitudinal difference between the Δf curve and the spherical aberration curve. Obviously both meanings of the same word cannot be correct. The diagrams of distortion (Fig. 9T) are misleading, for when a lens suffers from barrel distortion, all parts of the image are too small, the corners being excessively reduced in size; likewise in pincushion distortion all parts of the image are too large, the corners again being excessively so. Figure 9V, (b), is incorrect, for a single lens with central passage of the light cannot possess any lateral chromatic aberration. This is an aberration of the chief ray, and will appear only where the chief ray has been dispersed into a spectrum by eccentric passage through a lens. The Huygens' eyepiece is referred to in 9.11, line 1, as an achromatic system; this is, however, contradicted later in the same paragraph. There are two errors in labeling of lens cross-sections: in Fig. 10C, the diagram shows the Zeiss Topogon, not the Ross Wide-angle, and in Fig. 10G, the lens shown is the "Varo," not the "Zoomar." The Galilean telescope diagram in Fig. 10R is incorrect, for the eye is actually the exit pupil, and only those rays which enter the eye should be considered. The entrance pupil of a Galilean telescope is virtual and situated at a considerable distance behind the eye.

The book is very well produced, on good paper, and beautifully printed. A series of useful review problems has been included at the end of each chapter.—R. Kingslake, Eastman Kodak Co., Rochester, N.Y.

Electrical Engineers' Handbook -Electric Communication and Electronics, Vol. II, 4th Ed.

Edited by Harold Pender and Knox McIlwain. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. i–xiii + 1,564 pp. including approx. 130 tables and approx. 1,050 illus. + 54 pp. index. $5\frac{1}{2} \times 8\frac{1}{4}$ in. Price $8.50.

This edition has been entirely rewritten and enlarged to meet the widening fields of communication and electronics. Each section is written by an expert in that field and is accompanied by a bibliography.

The twenty-three sections cover a wide variety of electronic applications as well as fundamental properties of materials and

circuit elements. Frequency modulation, television and radar have been given considerable space.

As is the case with any handbook attempting to cover such a wide field, the space devoted to any one subject must be small compared to a textbook on that subject. In the present volume the editors and authors have shown good judgment in selecting tables and formulas to which a worker familiar with the subject may refer, and sufficient description so that one unfamiliar with the particular subject may obtain a good introduction to it.—Clyde R. Keith, 5 N. Terrace, Maplewood, N.J.

Television, Volume V (1947–1948)

Edited by Alfred N. Goldsmith, Arthur F. Van Dyck, Robert S. Burnap, Edward T. Dickey and George M. K. Baker. Published (1950) by *RCA Review*, Radio Corporation of America, RCA Laboratories Div., Princeton, N.J. i–x + 458 pp. + 3 pp. summary. 315 illus. 6 × 9 in. Price, $2.50, plus $0.20 per copy for postage to countries other than U.S.

Television, Volume VI (1949–1950)

Same editors and publisher. i–x + 402 pp. + 20 pp. appendix. 284 illus. 6 × 9 in. Price, $2.50, plus $0.20 per copy for postage to countries other than U.S.

Television, Volumes V and VI, are respectively the eleventh and twelfth volumes in the RCA Technical Book Series and the fifth and sixth volumes devoted exclusively to television.

The books are comprised of a compilation of reprints of articles by RCA authors which appeared in *RCA Review, RCA Licensee Bulletin, Broadcast News, Proceedings of the I.R.E.*, the Journal of this Society, *Communications, Teletech, Journal of the Optical Society of America, Electronics* and *Harvard Business Review*.

In the appendix of Volume VI is given a complete television bibliography of technical papers by RCA authors for the period 1929 to 1950. Of the total published within the periods covered by *Television, Volumes V and VI*, selected articles are reprinted in full, others in summary form only, while the remainder are omitted except for their listing in the bibliography.

The papers are presented in each of these volumes in six sections: pickup, transmission, reception, color, ultra-high frequency and general. Within each of these sections, distinct phases of television development are covered by three types of articles: (1) pure theory and analyses of performance factors, (2) new techniques and proposed new designs not yet reduced to practice and (3) descriptions of new equipment, facilities, methods, techniques and concrete applications of principles reduced to practice.

Material of the first type serves as a guide for the conception and development of advanced television designs of the future. An outstanding article by Otto H. Schade is entitled "Electro-Optical Characteristics of Television Systems." It is so advanced and basic as to be of permanent value as a text.

Material of the second type forms a basis of designs of tomorrow's improved television. An example is entitled "Standardization of Transient Response of Television Transmitters" by R. D. Kell and G. L. Fredendall.

Of the third type, descriptions of new equipment are published soon after the equipment design is completed. Thus, such descriptions represent the latest equipment as of that date. Examples are: "New Television Field Pickup Equipment Employing the Image Orthicon," by J. H. Roe, and "Development of a Large Metal Kinescope for Television" by H. P. Steier, et al. Descriptions of most of the major equipment and circuit features now constituting present-day television systems may be found in these two, together with preceding volumes of *Television*.

Television papers by RCA authors are highly authentic because the findings are the results of intensive and extensive activities of the writers in all phases of television, each of whom is a specialist in his particular field.

These volumes contain a wealth of authentic television information in a concise form and they should be included in every engineer's television library.—Fred G. Albin, 241 S. Wetherly Dr., Beverly Hills, Calif.

Proceedings of the National Electronics Conference, Vol. 5

Published (1950) by National Electronics Conference, Inc., 852 E. 83 St., Chicago 19. i–x + 581 pp. text + xi–xxi pp. Contents, Previous Issues. Approx. 600 illus. + numerous tables. 6 × 9 in. Price $4.00.

This book is intended to serve as a permanent record and handy reference of the papers presented at the National Electronics Conference in 1949. Since only a small group can attend such a conference, the publishing of this volume allows all engineers to receive the benefits of the papers. Many papers which are presented at such meetings are never published elsewhere, consequently this provides the only permanent record of these papers.

There is not sufficient space here to review each of the 59 papers included in the book. However, it can be said that the papers range from basic theory to component design and application. Subjects covered include audio-frequency, supersonics, magnetic devices, vacuum tubes, circuits, theory of communication, antennas, television, measurements, computers, electronic instrumentation and others. One paper, "The Magnetic Cross Value and Its Application to Subfrequency Power Generation," presented a very interesting new magnetic device. The analysis of the operation of this device was well presented. It is refreshing to find that we are still discovering new principles in magnetism, one of the older phases of electronics.

It is unfortunate that no attempt was made to group papers on the same general subject or to provide an index which would facilitate rapid exploration of the volume to find everything on a particular subject.

Since the discussion of papers at such meetings frequently adds important information it is regrettable that no comment on the discussions of these papers is included.

In spite of these shortcomings the N.E.C. is to be commended for publishing its Proceedings, and it is hoped that other conferences will soon follow suit.—Ogden Prestholdt, Columbia Broadcasting System, 485 Madison Ave., New York 22.

Manuel de Sensitometrie (3d ed.)

By L. Lobel and M. Dubois. Published (1950) by Publications Photographiques Paul Montel, 189, Rue Saint-Jacques, Paris (5e). 216 pp. 103 illus. 5⅜ × 7¼ in. Price 375 francs.

This elementary book gives the principal definitions concerning sensitometric measurements, some of the properties of the characteristic curve, and a review of the chief systems used for the definition of the negative emulsion speed. It includes a chapter on paper sensitometry and the choice of printing conditions, and another on sensitometry for positive films used by projection.

It also gives information on reversal development, including the influence of the solvent action and that of the second exposure, on intensifying and reducing processes, on the control of color photography and the use of the masking method.

Finally, about forty pages concern the elementary principles of sound recording and the application of sensitometry to sound film.

As regards the apparatus used in sensitometry, the descriptions are very short and the authors emphasize the densitometers designed by Mr. Lobel.

This booklet, despite a few errors and many oversimplifications, should be useful to amateurs and beginners in photographic science.—R. Pinoir, Kodak-Pathé, 30, Rue des Vignerons, Vincennes, France.

Journals Available: The following back numbers of the Journal are available from Mr. John R. Bizzelle, 419 West 48 St., New York 19, N.Y.: Oct. 1917, $1.00; Apr. 1918, $1.00; Sept. 1931 (2 cys) $.50 each; Nov. 1931, $.50; Jan. 1935, $.50; all 12 issues for 1942 at $.25 each; all 12 issues for 1943 at $.25 each; all issues for 1944 (except Mar., Apr. and May) at $.25 each; all 12 issues for 1945 at $.25 each; and Jan., Feb., May, June, July, Aug., Sept. and Oct. 1946 at $.25 each.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Allen, William H., Commercial Photographer. **Mail:** 721 E. Fayette St., Syracuse 3, N.Y. (A)

Barnes, Carl E., Director of Chemical Research, Arnold, Hoffman & Co., Providence, R.I. (A)

Beibin, Harold, Film Recording Engineer, Allen B. Du Mont Laboratories, Inc. **Mail:** c/o Brown, 240 W. 98 St., New York, N.Y. (A)

Besse, Armand, Sales Manager, Perkins Electric Co., Ltd. **Mail:** 9370 St. Hubert St., Montreal 12, Quebec, Canada. (A)

Clark, Walter M., Technical Photographer, Northrop Aircraft, Inc. **Mail:** 2907 Gibson Pl., North Redondo, Calif. (A)

Dare, Doug, Motion Picture Cameraman, Sam Hayes Productions. **Mail:** 600 N. Maple St., Burbank, Calif. (M)

Darmstaedter, Eric, Vice-President, Reeves Equipment Corp. **Mail:** 10 E. 52 St., New York, N.Y. (A)

Dierken, Kenneth C., American Television Inst. **Mail:** 534 Wellington, Chicago 14, Ill. (S)

Forbes, Richard B., Hollywood Sound Inst. **Mail:** 1021 Palm Ave., Los Angeles 46, Calif. (S)

Fung, David T., New Institute for Film and Television. **Mail:** 435 W. 123 St., New York, N.Y. (S)

Grossman, Milton B., Electrical Engineer, Otto K. Olesen Co. **Mail:** 10401 Tuxford St., Sun Valley, Calif. (A)

Hughes, Lafayette M., Jr., Producer and Director, Hughes Sound Films. **Mail:** 21 S. Downing St., Denver, Colo. (M)

Johnson, Carl M., Head, Technical Information Div., U.S. Navy Electronics Laboratory. **Mail:** 336 W. Upas St., San Diego 3, Calif. (A)

Katz, Leonhard, Engineer, Raytheon Manufacturing Co. **Mail:** 19 Ward St., Woburn, Mass. (A)

Kenworthy, N. Paul, Jr., 10710 Strathmore Dr., Los Angeles 24, Calif. (S)

Keough, James L., Still Camera, Projector and Movie Camera Repairman, Craig Movie Supply, and self. **Mail:** 6548 23d Ave., N.E., Seattle 5, Wash. (M)

Kish, Frank, Photographer, National Advisory Committee for Aeronautics. **Mail:** 4481 W. 51 St., Cleveland 9, Ohio. (A)

Kusack, William P., Chief Engineer, Balaban & Katz Television. **Mail:** Station WBKB, 190 N. State St., Chicago 1, Ill. (M)

Lantz, Donald R., Assistant Director, Dept. of Audio-Visual and Radio Education, International Council of Religious Education. **Mail:** 206 S. Michigan Ave., Chicago 4, Ill. (A)

Lewis, Louie L., Chief Engineer, WOI, WOI-FM, WOI-TV., Iowa State College, Ames, Iowa. (M)

Matilla, Augusto M., National Supply S.A. **Mail:** P.O. Box 2909, Caracas, Venezuela. (A)

Motts, Gordon H., Supervisor, Still and Motion Pictures, Army Field Forces, Bd. #4, Ft. Bliss. **Mail:** 613 Mission Rd., El Paso, Texas. (A)

O'Byrne, Frank E., General Manager, Queensway Studios. **Mail:** 277 Victoria St., Toronto, Ontario, Canada. (M)

Phelan, Charles W., Owner, Films for Television, Inc. **Mail:** Harbor Ave., Marblehead, Mass. (A)

Reiter, Abraham, Instructor, Audio Engineering, University of Hollywood. **Mail:** 3808 W. Alameda Ave., Burbank, Calif. (A)

Robyn, Abe, Sound Technician, Universal Recorders. **Mail:** 850½ N. Edinburgh Ave., Los Angeles, Calif. (A)

Shelton, Aaron, Chief Engineer, WSM-TV. **Mail:** 2901 23d Ave., S., Nashville 5, Tenn. (M)

Steadman, Loren L., 2911½ 11th Ave., Los Angeles 18, Calif. (S)

Williams, David L., Advisory Engineer, Lamp Div., Commercial Engineering Dept., Westinghouse Electric Corp., Bloomfield, N.J. (M)

Woodside, Robert L., Sound Technician and Mixer, U.S. Air Force, Lookout Mountain Laboratory. **Mail:** 8935 Wonderland Ave., Hollywood 46, Calif. (M)

CHANGE IN GRADE

Jacobsen, Roger G., Supervisor, Audio-Visual Installations, University of Washington. **Mail:** 11350 21st Ave., N.E., Seattle, Wash. (S) to (A)

DECEASED

Lyons, Thomas T., Projectionist, National Theaters Amusement Co., 444 W. 56 St., New York 19. (A)

Obituary

Albert S. Howell, Chairman of the Board of Bell & Howell Co., died at the age of 71 on January 3 in Chicago. He had retired from active service in 1940 from the company which he had helped form in 1907.

He was born in 1879 in West Branch, Mich., and became an apprentice at 16 for the Miehle Printing Press Co. He finished high school in night attendance and later studied in night classes at the Armour Institute of Technology. From his experience in his teens repairing motion picture cameras, his inventions led him to getting patents on 65 photographic devices.

Three of his inventions are credited as forming much of the basis for standardization on the 35-mm film width early in the 1900's and the ensuing rapid progress of the industry. His inventions were the Bell & Howell film perforator (1908), the continuous printer (1911) and a standard camera. His first patent was on a 35-mm projector and that led to the formation of the Bell & Howell Co.

Mr. Howell was an Honorary Member of this Society and he was honored in 1927 by receipt of the Wetherill Medal from the Franklin Institute. He was one of three men who have received life membership in the American Society of Cinematographers, the others having been Thomas A. Edison and George Eastman.

Meetings of Other Societies

Inter-Society Color Council, Annual Meeting, Feb. 28, Wardman Park Hotel, Washington, D.C. The ISCC meeting will consist of three sessions. In the morning a Discussion and Business Session will be devoted to presentation and discussion of various Color Problem Committee reports, and reports from chairmen of delegates from each Member Body. The afternoon session will consist of a symposium of reports and demonstrations on Color in Government, a program arranged under the chairmanship of Dr. Deane B. Judd. In the evening the Photometry and Colorimetry Section of the National Bureau of Standards will hold Open House for the group.

Optical Society of America, Mar. 1–3, Washington, D.C.

American Physical Society, Mar. 8–10, Pittsburgh, Pa.

American Physical Society, Apr. 26–28, Washington, D.C.

Acoustical Society of America, May 10–12, Washington, D.C.

American Physical Society, June 14–16, Schenectady, N.Y.

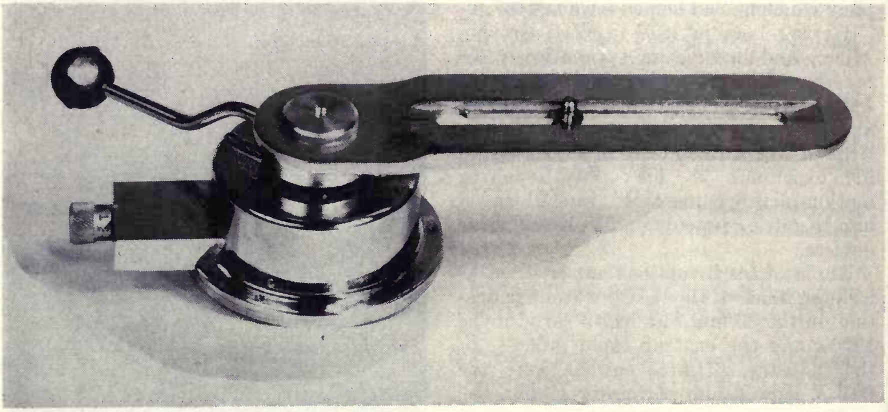
American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



The Hydra Pan Head is a new control device available from Hydra Pan Head Co., 2800 Clearwater St., Los Angeles 39, Calif. It is mounted on the tripod or tripod head and is hydraulically controlled to achieve maximum smoothness and horizon parallel. The Hydra Pan Head is designed for making murals with still cameras and panoramic pictures with motion picture cameras using telephoto lens.

Proceedings of the Symposium of Improved Electronic Components

This 236-page, illustrated book contains papers by 42 electronic authorities and experts in the military, manufacturing and engineering fields. The volume is the result of a symposium sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers and the Radio-Television Manufacturers Assn., with participation by the U.S. Dept. of Defense and the National Bureau of Standards. It contains articles on miniaturization, printed circuits, glass capacitors, quality resistors, improved tube design and the views of aircraft, naval and military experts. The sponsors have arranged distribution of the *Proceedings* at $3.50 a copy, postpaid if check accompanies the order sent to: The Tri-Electro Co., 1 Thomas Circle, Washington 5, D.C.

SMPTE Officers and Committees: The Roster of Society Officers was published in the May 1950 Journal. For Administrative Committees see pp. 515–518 of the April 1950 Journal. The most recent roster of Engineering Committees appeared on pp. 337–340 of September 1950 Journal.

Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems

Part I: Image Structure and Transfer Characteristics

By Otto H. Schade

The physical quality of motion picture and television images is determined by the transfer characteristic, the standard deviation or signal-to-fluctuation ratio, and the detail flux-response characteristics of the system. The performance of typical systems and system combinations is illustrated by examples permitting numerical comparison. The analysis of fluctuation levels("noise") in photographic processes, based on sampling theory, includes an evaluation of the sine-wave frequency spectrum of the deviation as modified by the "aperture" processes of the system. The sine-wave response characteristics of typical apertures are developed as well as an accurate method of determining the equivalent "resolving aperture" (point image) of practical devices from sine-wave response measurements. A new system of rating image-forming devices is thus developed permitting precise evaluation and comparison of components as well as of complete systems including the eye. Part I discusses the transfer characteristics of motion picture and television systems. Parts II and III, to be published at a later date, will contain an analysis of signal-to-fluctuation ratios and detail contrast.

INTRODUCTION

The quality of images reproduced over a television or motion picture system may be judged by a visual comparison with respect to three characteristics: tone scale, graininess and sharpness. Such a comparison may indicate that one image is more grainy than the other, has a longer or different tone scale, or has greater sharpness. These subjective impressions, however, are often difficult to separate. Differences in picture size, brightness, contrast and flicker, to mention only a few variables, may have a considerable effect on a visual evaluation of the image characteristics. The eye is not capable of performing a quantitative and objective analysis of image properties. It cannot, of course, be used at all to evaluate the quality of electrical images or image

Presented on April 20, 1950, at the Society's Atlantic Coast Section Meeting at New York, N.Y., by Otto H. Schade, Tube Dept., Radio Corporation of America, Harrison, N.J.

SYMBOLS

Note: Peak values are designated by a peak sign over the symbol, $\hat{B}$; average values by a horizontal bar, $\bar{B}$; and rms values by two vertical bars, $|B|$.

A	Picture area or frame area
B	Luminance (brightness)
B_o	Luminance of "black" level
C	Contrast range
D	Total photographic density
D^*	Density above fog and base density
ΔD	Density increment or density range of photographic image
d	Object distance or viewing distance
E	Exposure (unit: meter candle seconds) or voltage
E_1E_2	Exposure, index indicating order of process
$E_{1(o)}$	Exposure on first process determining "black" level
E_o	Bias voltage at "black" level
F	Focal length of a lens
g, G	Small- and large-signal transfer factors [Eqs. (8) and (9)]
I	Current
I_o	Current set to black signal level at transmitter
K	Constant
n	Number of samples, light quanta, silver grains, etc., according to index
O	Operating point, (signals $x = 0$, $y = 0$)
q_e	Charge of one electron [Eq. (6)]
q_o	Energy of one light quantum (see footnote on p. 141)
S	Film speed
S_e	Photosensitivity, practical unit: microamperes/lumen
x, y	Input and output signal values measured from 0 (general)
$\dot{\gamma}$	Gamma at a point of an operating characteristic [see Eq. (10a)]
δ	Diameter of a sampling or resolving aperture
δ_s	Lens stop diameter
ϵ	Quantum efficiency (over-all)
τ	Transmittance factor
ψ	Flux

signals in intermediate stages of an imaging process, nor can it be used to evaluate or predict the effect of changes or improvements which are possible and are expected to occur upon further development of an imaging process. Television is a young and complex art with a large number of old and new variables. It will take some time to eliminate temporary defects and attain consistently the level of image quality of which the system is capable.

Various evaluations of the quality and particularly of the sharpness of television images have been reported in the literature. A careful subjective comparison of the relative sharpness of images transmitted over television channels with different passbands appears to be a most convincing and direct method of determining, for example, the loss of image sharpness caused by reducing a 4.25-mc (megacycles) television channel to 2.7 mc (present coaxial cables) or the gain in sharpness when the channel is increased to 6 or 8 mc.

The results of these tests, however, depend to a great extent on the subject material, the source of image signals and the excellence of the system components. It is obvious that the reproduction of a subject which does not contain fine detail cannot be improved by providing a system capable of reproducing finer detail. A standard 35-mm motion picture film, when compared with the original scene, is certainly not a perfect source of image signals.

It is well known that duplication of a motion picture by a second motion picture process, identical with the original process, results in a marked degradation of detail signals and sharpness. Subjective observations in which a 35-mm motion picture is used as a source of image signals to evaluate a television process are, therefore, hardly conclusive. The inadequacy of such observations is particularly evident when the quality of the duplicating process approaches or exceeds that of the motion picture source, because even an ideal imaging process can but reproduce the quality of the signal source. Ten years ago 35-

mm motion picture film seemed adequate for television tests as a source of picture signals. Film scanners were then ahead of direct-viewing cameras in quality but still inferior to the motion picture. In subsequent years, however, the resolution obtainable with camera tubes and kinescopes has increased considerably. This increase has been obtained in a large measure by providing better operating conditions for the tubes. The resolution of the standard 35-mm motion picture was soon exceeded in laboratory tests and larger, sharper test patterns and even better lenses are required to test the image sharpness obtainable with a standard television channel of 4.25 mc. It is, therefore, desirable and necessary to employ objective methods and a unified approach in an analysis of image quality to coordinate and compare the characteristics of optical, electrical, photographic, and visual processes. When the photographic process is used as a link in a television process it is to be expected that the photographic process must be adapted to the characteristics of the television process and its imaging quality may then, by itself, be quite unsuitable for direct observation by eye.

The principles for an objective evaluation of image quality have been discussed in an earlier paper.[1] An evaluation of practical systems and system combinations, such as in television recording, requires an analysis of existing processes in greater detail. The transfer characteristics, relative fluctuation levels (grain and noise), and the detail signal response (resolution, detail contrast) of the various system components and their combinations will, therefore, be treated in that order.

A. IMAGE STRUCTURE AND THE SAMPLING PRINCIPLE

A common basis for an analysis of image quality is indicated by the fact that all images have a structure. When an apparently uniform area is examined under sufficient magnification, at least theoretically, it is found to consist of particles or groups of particles arranged in a regular or a random fashion. The particles or groups are, to use a general term, "samples" of energy or matter which, according to number, arrangement and size, determine the image quality. The imaging process is fundamentally a sampling process. The light flux from a scene, the image flux passing through a lens, the electron currents in television tubes or amplifiers, are a flow of discrete samples. Samples of light energy, known as "quanta" of light, are emitted from points of an object. A small fraction of these samples is collected and directed by the camera lens to form an instantaneous image of the light distribution at the object. The degree of continuity in the image information is obviously dependent on the number of samples; with respect to an area, continuity depends on the sample density.

In practical processes the optical image is formed on a photosensitive material which releases photoelectrons when it is bombarded by light quanta. This sample-conversion process generally reduces the number of samples, but it permits their accumulation and storage. In the television process the electrical samples can be stored directly as a "charge image." In the photographic process the photoelectrons combine with silver ions in a secondary conversion process to form submicroscopic silver samples, which, in turn, can be accumulated and stored as a "latent image." Following these processes, which take place upon "exposure" of a light-sensitive surface, are processes of multiplication or "development" in which the electron energy or the mass of the silver sample is increased by large factors to become sufficient for the transmission of information and the control of light sources for image reproduction.

1. Continuity, Sample Number and Sample Size

The energy or mass of the original sample is increased by supplying and attaching to it a group of "secondary" electrons or atoms, thus forming a new sample unit. If a sample is visualized as a three-dimensional particle, it can be seen that the original sample may be enlarged in one dimension (height, intensity) but still retain its original cross section; or, it may be enlarged in two or three dimensions and thus increase in cross section. In a three-dimensional development (film) the increase in sample size must be limited because it introduces an error in sample position.* In all cases, however, the development must be uniform for all samples. The optimum value of the sample size depends on a number of factors to be determined later. The sampling process gives, in principle, a discontinuous picture information. Continuity and uniformity of an area are, in a strict sense, illusions. These illusions depend on restricting variations in sample density in an area representing a constant level to a threshold value, a certain small *deviation* determined by the method of observation. It is not difficult to see that deviations in density become larger when the sample number per unit area decreases, and that restoration of continuity requires, then, a process of filling out the spaces between samples and a supply of additional samples. It is logical to attach these additional samples in equal numbers to the original sample units thus expanding the size of the unit representing one original sample. This process obviously does not supply new information, but rather causes a fusion of possible detail in areas equal to or larger in diameter than the spacing between original sample centers. The desired uniformity requires in most cases overlapping of the expanded areas.

* The silver speck forms on the outside of a bromide crystal.

2. Integration of Samples by Low-Pass Filters (Apertures)

A device limiting the observation or transmission of detail or fluctuations in one dimension (time) by fusing and integrating all faster fluctuations is known electrically as a "low-pass filter." A similar optical device spreading light samples in two dimensions (over a small area) when point sources of light are imaged, is an "aperture." It is well known that the shape and area of the point image made with a pinhole camera are controlled by the size and shape of the pinhole aperture. The point image itself may be identified as the "sampling aperture" of the imaging device. *The sample aggregate or figure of confusion formed by an imaging device and representing a mathematical point is thus defined, in general, as the "sampling aperture" in the image,* and the effect on image definition and limiting resolution is an "aperture effect" or a two-dimensional low-pass filter effect. Because of their resolution limit, lenses, dot or grain structures, mosaics and the eye are two-dimensional low-pass filters which integrate samples within areas equal to their sampling aperture. It is, therefore, unnecessary for an image-reproducing process to integrate a dot or line structure which cannot be resolved by the eye, nor is it necessary to reproduce detail which cannot be seen by the eye in the final image. The characteristics of vision as a sampling process are thus needed as a standard of comparison.

Two-dimensional images are an assembly of point images produced simultaneously (lenses, printing, etc.), or in sequence (facsimile, television) by moving one sampling aperture over the image area. Uniform coverage is obtained with one aperture by "scanning" the image area along parallel paths (lines), the aperture moving at a constant velocity in the "horizontal" direction along the scanning line and progressing stepwise by constant increments in the "vertical" direction. In this manner *two-*

dimensional information under the scanning aperture is translated into *one-dimensional information:* a signal current varying in intensity with time. The change in dimensions indicates a quadratic relation between the diameter (and resolution) of the scanning aperture as a two-dimensional filter and the passband of an electrical channel. It likewise indicates a change of units and quadratic rules for combining optical and electrical "aperture" effects.[1]

The foregoing discussion has shown the similarity of elements and functions which must be performed by an imaging system. Before specific characteristics are treated, it will be of interest to discuss a number of general relationships which are readily understood from the sampling principle and must be satisfied before images of a given quality can be produced.

3. *Light Energy, Image Quality and Image Size*

The image quality is controlled basically by the energy levels obtainable in the imaging process. The higher the useful level of energy and the larger the number of samples, the higher can be the image quality obtainable by the process. A given image quality is, therefore, characterized by: (1) the total number of sample aggregates in the image frame; (2) the relative accuracy of sample density and location in the frame with respect to the original; and (3) the size of the sample aggregate with respect to the frame size. Hence, when the distribution and the total number of samples in the frame area of a television image or a photographic image are held constant and the sample size or sizes are expanded or contracted in proportion to the frame size, the quality of the image remains constant and is *independent of the frame size.* Not only does the quality remain constant but it is also obtainable with the same scene illumination, depth of field and exposure time by maintaining a proper relation among the optical parameters. These relations may be illustrated by examining the photographic process.

It is known that the photosensitivity of the primary process in photographic film is, in principle, independent of the grain size built into a particular film type. To make one grain developable, certain numbers of light quanta, photoelectrons, and silver atoms are required whether the grain is large or small. The ratio of the number of grains developed in an area to the total number of light quanta received by the area is the over-all "quantum efficiency" of the film process (including development).* This quantum efficiency can be determined from the normal sensitometric curves of density, D, as a function of exposures, $\log E$, and a grain count.

The light flux of one meter candle per second, $E = 1$, of *white* light represents the quantities:

$$1 \text{ lm/sq m} - n_o\, q_o/\text{sq m} = 1.3 \times 10^{16} \text{ quanta}\dagger/\text{sq m}$$

The number, n_o, of light quanta, q_o, incident on 1 sq mm of film surface during exposure time is, therefore:

$$n_o/\text{sq mm} = 1.3 \times 10^{10}\, E \quad (E \text{ in meter-candle seconds}) \qquad (1)$$

The number, n_s, of silver grains obtained with a given value E, depends on the spectral response and the degree of development, γ, of the film and is given by:

$$n_s/\text{sq mm} = n\, D^* \qquad (2)$$

where D^* is the film density above the densities of "fog" level and film base, and n is the number of equivalent grains at $D^* = 1$ for the particular film type.

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* It is apparent that the spacing between developable centers is an important factor.

† This number is the number of quanta in the wavelength range, $\lambda = 0.40$ to $0.73\ \mu$ from a black body at 5400 K, which would give one lumen. Radiation outside this range is excluded because it contributes nothing to the luminous output.

The effective quantum efficiency, ϵ, is, therefore:

$$\epsilon = n_s/n_o = n\ D^*/E\ 1.3 \times 10^{10} \quad (3)$$

The quantum efficiency of film has its highest value in the toe region of the transfer characteristic, $D = f$ (log E), and decreases for larger values of D or E. The total light is given by the number of grains in the image frame multiplied by the quantum efficiency; in conventional units it is the exposure multiplied by the film area, A (in square meters):

$$\text{Light energy} = E\ A \text{ lm sec} \quad (4)$$

For a constant grain number and quality, the light energy must remain constant when film and grain areas are shrunk or expanded in proportion. The exposure, E, will thus change in inverse proportion to the frame area, A; and the film speed, $S = K/E$, will change in direct proportion to the frame area. (K is a constant.)

An analysis of the optical parameters for the exposure of the film furnishes the following facts. If a distribution of the light flux emitted from object points according to Lambert's law is assumed, the quantum efficiency of the camera lens is expressed by the ratio of image flux, ψ_i, to object flux, ψ_o, and given by:

$$\psi_i/\psi_o = \tau(\delta_s/2d)^2 \quad (5)$$

for the practical condition, $d \gg \delta_s$, where τ is the transmission factor of the lens, δ_s, the stop diameter, and d, the object distance. For a given angle of view and object distance the "depth of focus" is a geometric factor controlled by the lens stop diameter, δ_s. The requirements of a constant quantum input [Eq. (4)] and depth of focus are thus fulfilled by a constant lens stop diameter, δ_s, independent of the size of the image formed by the lens. The focal length, F, of the lens must be changed in proportion to the image diagonal or the square root of the area to maintain the viewing angle, $F \propto A^{1/2}$; and the f/number of the lens, therefore, also changes as the square root of the image frame area, A. Finally, the lens resolution in lines per millimeter must change in proportion to $1/A^{1/2}$, i.e., it must be inversely proportional to the f/number, which is theoretically true. The relations of the various parameters for constant image quality are summarized in Table I.

A given image quality (including depth of focus) requires a certain lens-stop diameter and a scene illumination which is determined by the quantum efficiency of the film process. The image quality is theoretically independent of the size of the image as long as the relations in Table I can be fulfilled. The diffraction of light sets a lower limit to the f/number at f/0.5 for refractive

Table I. Requirements for Constant Image Quality in a Frame Size of Area A.

Image Properties		Lens Properties		Photosensitive Surface and Signal Development	
Light flux	= constant	Focal length	$\propto A^{1/2}$	Quantum efficiency	= constant
Graininess	= constant	Lens diameter	= constant	Conversion efficiency (Signal development)	= constant
Tone range	= constant	f/number	$\propto A^{1/2}$	Sample number and distribution (grain)	= constant
Sharpness	= constant	Resolution	$\propto 1/A^{1/2}$	Sample diameter	$\propto A^{1/2}$
Viewing angle	= constant			Resolution	$\propto 1/A^{1/2}$
Depth of field	= constant			Gamma	= constant
				Speed rating	$\propto 1/A$

lenses. The smallest practical frame dimension, however, is limited to larger values by mechanical tolerances, difficulties in design and correction of lenses, and difficulties in the manufacture of films having adequate grain sizes, distribution and uniformity.

The question whether a 16-mm motion picture film process can be equal in quality to a 35-mm process for identical lighting conditions has in principle, been answered in the affirmative. It remains to be shown by analysis whether lenses and film of adequate characteristics are available.

The relations given in Table I are valid also for the television process.

The fundamental independence of picture quality and image size is demonstrated by a variety of kinescope and camera-tube sizes. Mechanical tolerances, insulation problems, heat dissipation, grain sizes, current densities and other technological difficulties impose limits on the size reduction of practical tubes. The fact that television images utilize a single image surface to generate or reproduce "live" images introduces a number of difficulties which are not found in motion picture systems. The screen of a small kinescope for theater projection, for example, must be capable of dissipating continuously the total input power. A motion picture frame, on the other hand, is exposed to the projector light flux and heat for only $\frac{1}{24}$ sec. Small defects or dust particles on a camera-tube surface are permanently visible and present a serious problem; similar defects in each frame of a projected motion picture can hardly be noticed for statistical reasons.

A simple comparison of the film process with the electrical process of television can be misleading in various respects because of differences in the low-pass filter response or "aperture response" of an electrical channel which must be considered when the requirements for equal performance are evaluated.

To equal the quality of a 35-mm motion picture negative a television camera tube such as the *image orthicon* must be capable of converting light quanta into useful electrons with an equal over-all quantum efficiency. Operation with a light range in the order of 30 to 1 reduces the electron storage in the tube from its short-range value of unity by a factor of approximately 2 in the low-light range. Absorption of photoelectrons by a mesh electrode and the addition of a fluctuation level from an electron-discharge beam, which may be likened to a high "fog" level, require a further increase of 3 to 1 in exposure. To compensate for these inefficiencies, the primary quantum efficiency of the photocathode of the tube must be in the order of 6 times the over-all efficiency of the film process. A primary quantum efficiency of 100% means that one electron charge, q_e, is emitted by one light quantum.* With the electron charge

$$q_e = 1.6 \times 10^{-19} \text{ coulombs} \qquad (6)$$

a quantum efficiency of 100% results in a photocurrent:

$$I = 1.3 \times 10^{16}\, q_e = 2080\ \mu\text{a/lm} \quad (7)$$

The quantum efficiency of 1% is, hence, obtained with a photocathode sensitivity, $S_e \simeq 20\ \mu$a/lm.

When this quantum-efficiency value is divided by six to obtain the equivalent over-all quantum efficiency of an image orthicon with $S_e = 20\ \mu$a/lm, the result is 0.16%. This value is in the same order as that of the fastest film types with normal development. Photosensitivities equal to and higher than the above value are obtained consistently in commercial tubes and there is evidence that much higher values will be obtained in the future.[2]

* The spacing factor does not appear in this conversion because the photocathode of the image orthicon is a continuous photosensitive surface.

B. TRANSFER CHARACTERISTICS

1. *Transfer Factors and Gamma*

The relation of "sample" numbers or sample densities of the output and input flux of an imaging device or system is described by transfer characteristics. A truthful and undistorted reproduction of light values by an imaging process requires that the intensities and ratios between light values in the object be duplicated in the image. The corresponding over-all transfer characteristic in linear coordinates is a straight line; the system response is linear. This ideal performance can be obtained by a combination of components having linear or nonlinear transfer characteristics. In practical processes the transfer of large light ranges is limited at the low-light end of the range by fluctuations due to lack of samples or by a light "bias." At the high-light end of the range it is limited by saturation effects because of limitations in the sample supply or storage capacity of system components.

The graphic representation of transfer characteristics in linear or logarithmic coordinates is a useful step in evaluating and combining their properties. The transfer characteristics of electron tubes are usually plotted in a linear-coordinate system which is convenient for evaluating the effects of constant additive or subtractive levels, "biasing" potentials or currents, rectification effects, distortion, and the transfer factors (signal ratios) for large and small signals.

The nonlinearity of the characteristics encountered in image "transducers" such as photographic film, television camera tubes and kinescopes are particularly evident when the characteristics are plotted in linear coordinates, as shown in Fig. 1. In many cases a signal-conversion process has a transfer characteristic following a law of diminishing returns such as an exponential characteristic or a power law, $y = x^{\dot{\gamma}}$, where the exponent, $\dot{\gamma}$, is smaller than unity. Either of these characteristics may be modified by secondary effects to produce characteristics of the type shown in Fig. 2, and exemplified by the eye, photographic film (density, D, versus exposure, E, in Fig. 1), the iconoscope, and image orthicon. It is evident that characteristics of this type can cover a larger range of input-signal energy with a given sample number and storage capacitance than a linear characteristic. The "compression" and the transfer of incremental signals by fewer samples requires, however, a subsequent

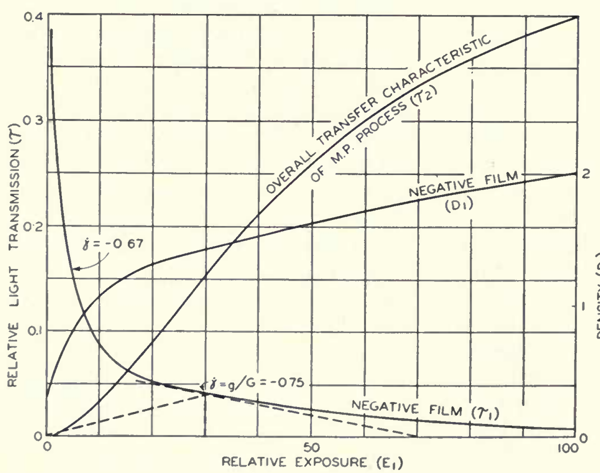

Fig. 1. Photographic transfer characteristics in linear coordinates.

re-expansion of signal or light values by a transfer characteristic with a higher exponent ($\dot{\gamma} > 1$, see Fig. 3) in order to restore over-all linearity. (Compare curve of M.P. process in Fig. 1.) A good balance of gradation values depends on maintaining the ratio, g/G, of the *incremental signal transfer factor*

$$g = dy/dx \tag{8}$$

to the *large signal transfer factor*

$$G = y/x \tag{9}$$

substantially constant over the transmitted light range. The signal values, x and y, are measured from the operating point O.*

A plot of an *operating characteristic* for unidirectional signals in logarithmic coordinates will, of course, never show the operating point, O, which is located at the origin of the coordinates.

It is readily shown that the *transfer ratio*, g/G, is equal to the exponent, $\dot{\gamma}$, when the operating characteristics are expressed as a power law. When plotted in logarithmic coordinates, the slope, $d(\log y)/d(\log x)$, of the characteristic is equal to the transfer ratio, g/G, because

$$d\,(\log y) = \frac{1}{y} \log_{10^e} d_y$$

$$d\,(\log x) = \frac{1}{x} \log_{10^e} d_x$$

and

$$\frac{d\,(\log y)}{d\,(\log x)} = \frac{d_y}{d_x}\Big/\frac{y}{x} = g/G \tag{10}$$

for the condition that the operating point is the origin of the coordinate system.

In photographic terminology the maximum slope of the film transfer characteristic, $D = f\,(\log E)$, has been termed the "gamma" of the film. The slope or gradient at any point may be defined as the *point gamma*, $\dot{\gamma}$. Because of the identity, $D = -\log \tau$ (τ = transmittance), the point gamma equals the log–log slope:

$$\dot{\gamma} = d\,(-\log \tau)/d(\log E) \tag{11}$$

It is, therefore, suggested that Eq. (10) be adopted as a general definition of the point gamma, i.e., for the condition $x = 0$, $y = 0$ at the operating point O:

$$\frac{d(\log y)}{d(\log x)} = \frac{d_y}{d_x}\Big/\frac{y}{x} = g/G = \dot{\gamma} \tag{10a}$$

This definition agrees in every respect with Equation (11) and requires that the operating point O, be placed always at the origin of the coordinate system. The point gamma, $\dot{\gamma}$, of a sensitometric-film curve can thus be obtained from a linear plot of the transmittance characteristic, $\tau = f\,(E)$, shown in Fig. 1, by determining the transfer ratio, $g/G = -\frac{(d\tau)\,E}{(dE)\,\tau}$, or from a logarithmic plot as the slope $d(\log -\tau)/d(\log E)$.* These

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* It is well known in electron-tube engineering that the operating point can be located by an electrical bias anywhere on the transfer characteristic of an amplifier stage without transmitting the d-c component at the operating point. For unidirectional signals the operating point of an electronic amplifier normally does not coincide with minimum signal values but with the average values of the signal unless a d-c restorer or black-level setting circuit is used. The operating point of photoelectric or electrooptical transducers such as camera tubes or kinescopes cannot be moved along their static transfer characteristic because it is impossible to eliminate a steady light bias, $x_{(o)}$ or $y_{(o)}$, which remains as a minimum exposure, $E_{1(o)}$, or as a luminance, B_o, in the optical input or output signals. In these cases, the operating point, O, can be moved only along the *electrical* coordinate (y-axis (I) for camera tubes, x-axis (E) for kinescopes), the optical coordinate of the operating point remaining at zero value.

* It is noted that the gamma of a negative or positive film is a negative quantity, while a reversal film has a positive gamma. In use the sign is usually neglected.

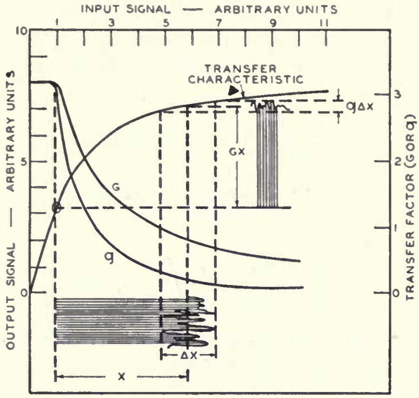


Fig. 2. Signal compression due to transfer characteristic following power law with exponent less than unity.

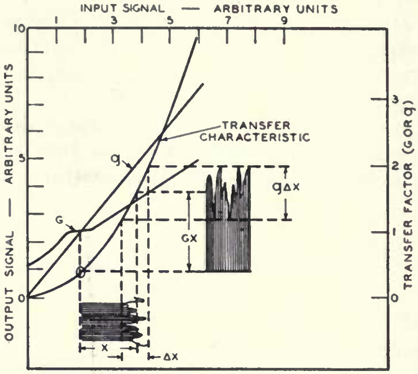


Fig. 3. Signal expansion due to transfer characteristic following power law with exponent greater than unity.

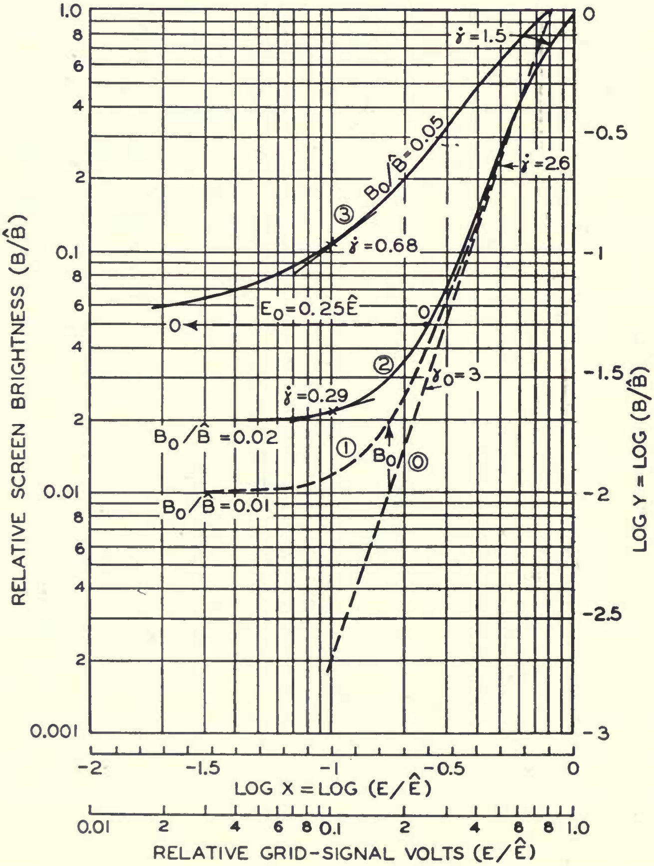


Fig. 4. Effect of additive or subtractive constants on point gamma of kinescope transfer characteristics.

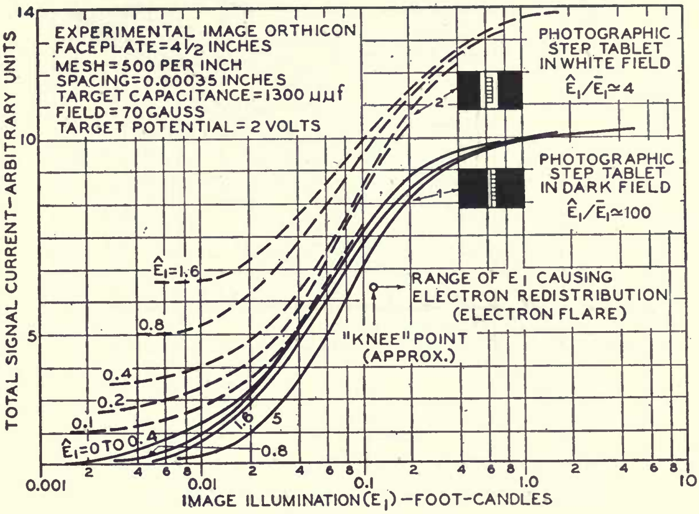


Fig. 5. Dynamic transfer characteristics of an image orthicon containing d-c signal components.

methods of determining the point gamma apply to all types of transfer characteristics. Additive signal constants, such as a superimposed light bias, B_o, on a film or a kinescope screen alter the value, G, the shape of the characteristic curve in log–log coordinates and, hence, $\dot{\gamma}$.

The effect of additive or subtractive signal constants on the point gamma may be demonstrated on the kinescope transfer characteristic shown in Fig. 4. The theoretical electrical characteristic, O, of the kinescope has a gamma of three. Due to phosphor saturation or loss of current in electron guns, the gamma, $\dot{\gamma}$, of the high-light curve section is reduced. Scattered light or ambient illumination represents an additive signal constant, B_o, in the order of 1 to 2% which, when added to all B-values, produces the *dynamic characteristics* (curves 1 and 2) having a toe.

In certain cases (television recording) it is desirable to increase the gamma in the low-light range. The grid-bias voltage for zero signal is then moved above the cutoff value by a voltage bias, E_o. This displacement of the operating point along the x-signal coordinate requires that the characteristic be redrawn by subtracting E_o from all signal values to furnish the *operating characteristic* curve 3. The light bias, B_o, however, which is caused by E_o, cannot be subtracted and remains in the optical output signal. The increase of $\dot{\gamma}$ due to E_o in the low-light range is obvious from the drawing.

2. *Transfer Characteristics of Television Camera Tubes*

A family of *image-orthicon* transfer characteristics[1] plotted in semilogarithmic coordinates and containing d-c components caused by optical and electron "flare" is shown in Fig. 5. Measurements with various image-orthicon types have shown that the shape of the transfer characteristics is determined by the operating mechanism of this type. The characteristics of different tubes differ, therefore, mainly in the numerical values of the scales. These differences are determined by the target capacitance

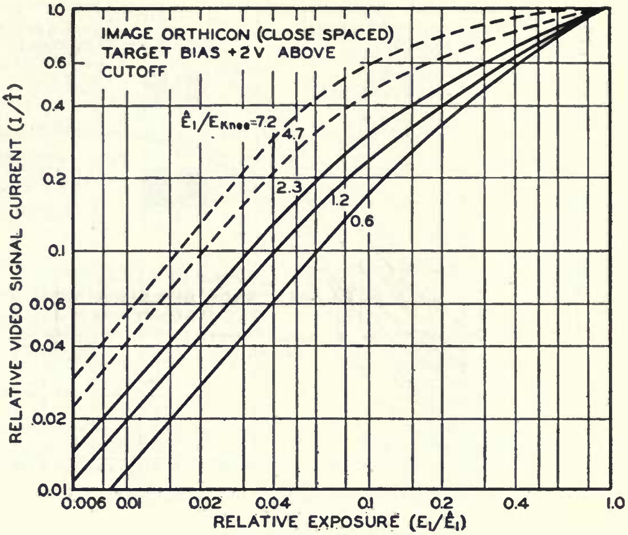


Fig. 6. Dynamic transfer characteristics of close-spaced image orthicons.

secondary-emission ratios, and photosensitivity of the particular type. In normal operation the "flare"-current or d-c black-level current, I_o, is subtracted by setting the video black-level signals to zero. The resultant transfer characteristics, letting $I_o = 0$, redrawn in logarithmic coordinates (Fig. 6), are typical dynamic *operating characteristics* for the image orthicon.* The dashed curves represent the condition of overexposure which produces undesirable edge effects.

The change of gamma in the transfer characteristics of television camera tubes with increased exposure comes from two causes: (1) diminishing collection of secondary electrons (photoelectrons in the iconoscope) from high-potential target areas; and (2) scattering of the uncollected electrons or of flare light over a portion of or the entire target area.

The first effect is desirable and similar to the expedients used for obtaining low-gamma film characteristics, i.e., incomplete development. The second effect, light- and electron-flare, is undesirable as it may introduce edge effects, level variations and a threshold for low-light values. Electron "flare" in image orthicons can be particularly undesirable because of its nonuniform distribution.

The d-c black-level current, I_o, increases with exposure because of optical and electron "flare." The "black" signal level is, therefore, actually a gray signal value (see Fig. 5) but may be reset at the transmitter to a perfect black signal value by subtracting the d-c signal component. The signal range which can be seen on the kinescope screen depends, of course, on the kinescope brightness range and the over-all gamma of the system.

The changes in the gamma of the camera-tube characteristics obtained by varying the exposure are shown in Fig. 7. A high exposure (broken-line curves in Fig. 6) reduces the gamma in the high-

* The relative exposure is specified by the ratio of the high-light exposure, $\hat{E}_1$, to the exposure, E_{knee}, where the high-light values are located at the shoulder or "knee" of the transfer characteristic.

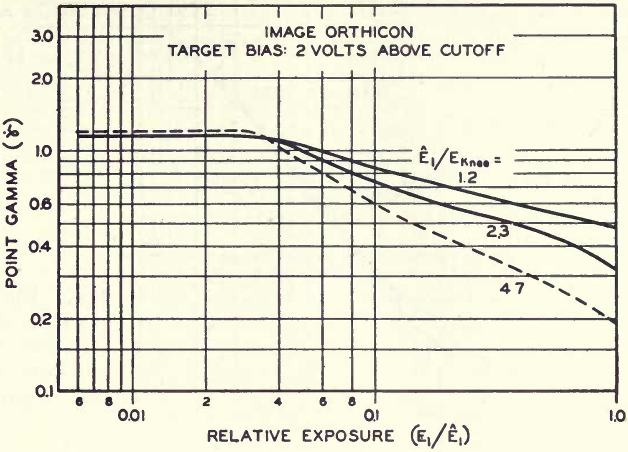


Fig. 7. Point gamma of transfer characteristics given in Fig. 6.

Figs. 8 a,b and 9 a,b are on plate pages 170 and 171.

lights and increases electron redistribution which causes strong local flare and distortion of black levels, overemphasizes edges and defects, and coarsens fine gradations. (See Figs. 8a and 8b.) A lower normal exposure (curve 1.2 or 2.3, Fig. 6) has a finer natural tone scale and if desired can be corrected electrically to a lower gamma. (See Figs. 9a and 9b.) These characteristics are duplicated by the commercial image-orthicon types[3] with 3-in. face plates.

Rendition of gradation in fine detail (texture) requires a low level of random fluctuations and spurious signals, and good but not overemphasized resolution. It is well known that spurious detail signals such as those caused by dust particles, small scratches, or a collector mesh structure go unnoticed in larger storage surfaces (films, targets) but can cause considerable difficulty in small image surfaces because of the high magnification on the final viewing screen. A larger target surface results in higher resolution and better texture because of the reduction of defects and mesh structure in proportion to image size. It also results in a lower fluctuation level because of increased storage capacitance. A larger target surface can be combined with a small optical image on the photocathode of the image orthicon by electrical image magnification. (The effect of a mesh structure will be discussed further under resolution.)

The dynamic transfer characteristics of the *iconoscope* are shown in Fig. 10 and are replotted in log–log coordinates in Fig. 11. These characteristics may again be regarded as typical when scalar values are considered as relative values which may vary for different tubes and tube sizes (1848 or 1850). As in the image orthicon, the combined effect of optical and electron flare (redistribution of electrons) causes the fundamental effect of raising the black-level signal, although the d-c level signal is normally not transmitted. Because of the fairly uniform distribution of the flare light and "flare-electrons" over the target, the black-level current depends more accurately on the average illumination, $\bar{E}_1$ of the image surface. Subtraction of the d-c level signals, I_o, furnishes the

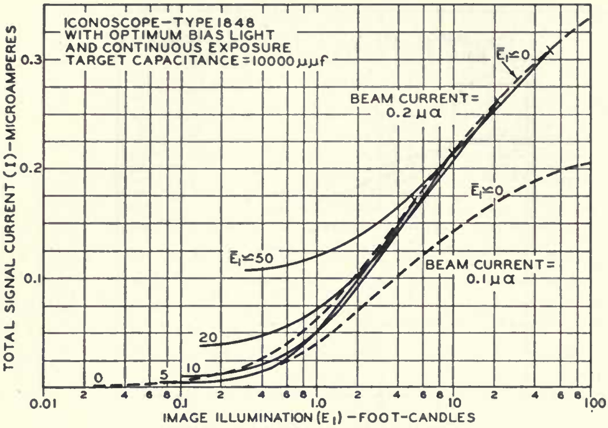


Fig. 10. Dynamic transfer characteristics of iconoscope containing d-c signal component.

operating characteristics such as $\bar{E}_1 = 5$; $I_o = 0.01$ in Fig. 11.

Although desirable in its effect of increasing the exposure latitude of the camera tube, the mechanism of incomplete electron collection and subsequent redistribution can cause excessive flare and nonuniform levels (shading, dark spot).

The orthicon is a camera tube having a linear transfer characteristic ($\gamma = 1$) and is free of redistribution effects. The linear relation of signal current and exposure, however, requires operation with high charges and large currents to accommodate the highlights in normal scenes. In practical designs difficulties in maintaining adequate resolution with high-beam currents limit the maximum useful storage capacitance and seriously impair the "signal-to-noise" ratio in the medium- and low-light region of the kinescope image when the system is corrected to approach a linear over-all transfer characteristic (discussed in Part II).

Storage camera tubes with substantially linear response such as the orthicon, the British C.P.S. Emitron, and certain types of Vidicons[2] (an orthicon type with photoconductive target) have, therefore, a short exposure latitude requiring low-contrast scene lighting, subdued highlights and critical control of camera-tube exposure.

An analysis of fluctuation levels in television images (Part II) points out that a natural and constant gamma in the charge storage mechanism of the order of $\gamma = 0.5$ (not by redistribution) overcomes the above limitations; the tube operation remains within the boundaries of practical signal development by electron beams. The characteristics of such a camera tube are, therefore, of interest for comparison with commercial tube types. Its transfer characteristic in log–log coordinates is a straight line with the constant slope, $\gamma = 0.5$.*

The operating characteristics of camera tubes are sections of the dynamic transfer characteristic extending upward from a minimum exposure value, $E_{1(o)}$ and corresponding video signal current I_o. The zero point of the operating characteristic is, therefore, a function of the scene contrast range. The value, $E_{1(o)}$, depends further on the interpretation by the camera operator. His

* The author was informed some time ago by Dr. A. Rose of the RCA Laboratories at Princeton, that one-half power-law transfer characteristics could be obtained with photoconductive targets.

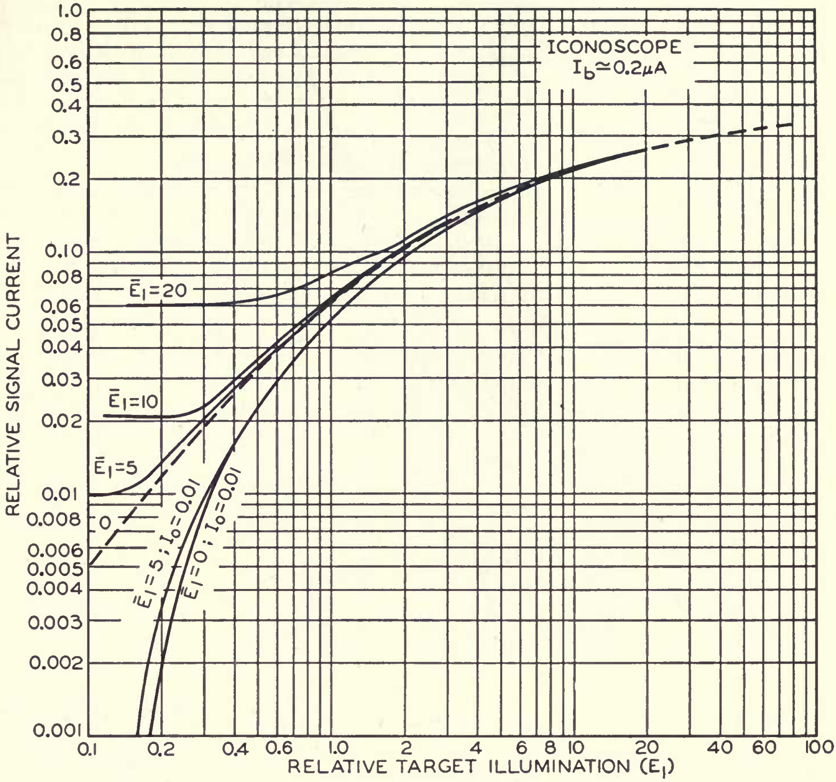
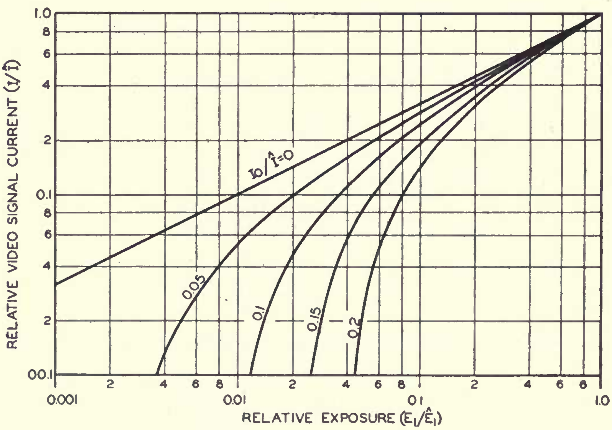


Fig. 11. Iconoscope transfer characteristics of Fig. 10 replotted in log–log coordinates.

Fig. 12. Operating characteristics of camera tube having a transfer characteristic following a one-half power law.



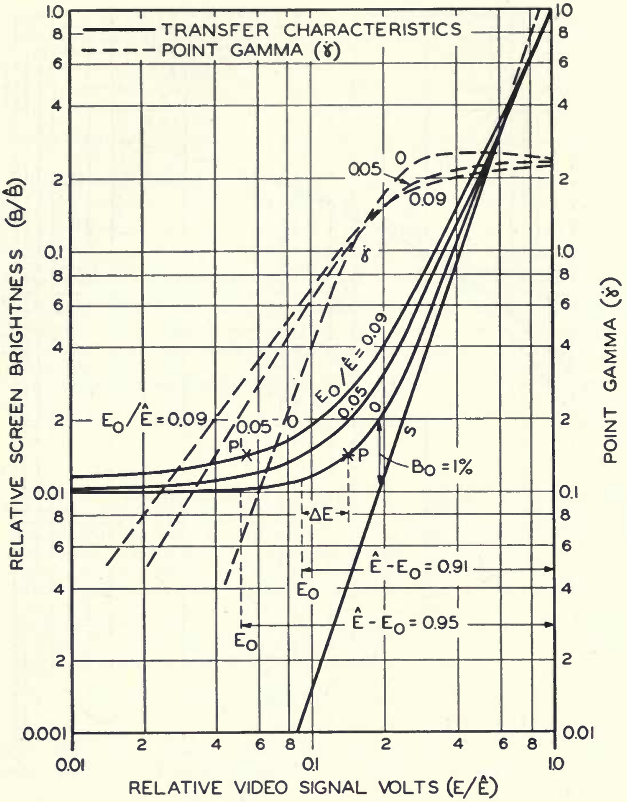


Fig. 13. Operating characteristics and point gamma of kinescope.

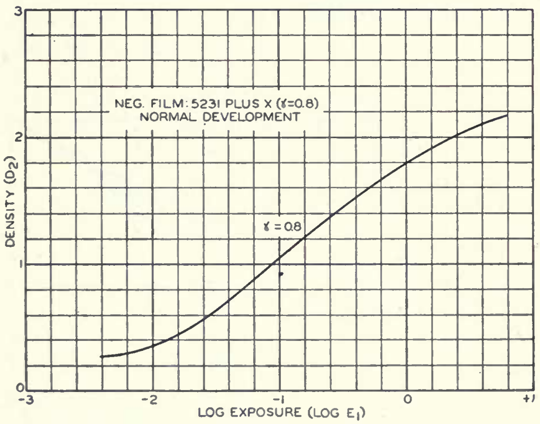


Fig. 14. Transfer characteristic of Plus X negative film.

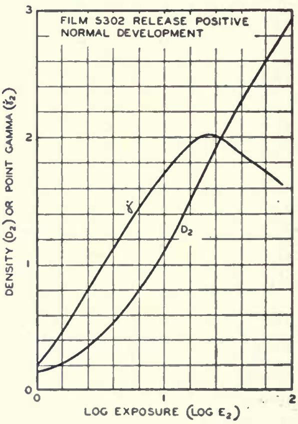


Fig. 15. Transfer characteristic and point gamma of fine-grain release positive film.

decision of letting a certain exposure, $E_{1(o)}$ represent a "black level," and setting the corresponding video current, I_o, to zero level, corresponds to the subtraction $I' = I - I_o$ and the expansion of this value by gain adjustment to a normal signal amplitude by $1/(\hat{I} - I_o)$. Camera-tube operating characteristics are, therefore, derived from the primary dynamic characteristic by changing the video current, I, at any given value, E_1 to the operating current:

$$I' = (I - I_o)/(\hat{I} - I_o) \qquad (12a)$$

A reduction of the exposure range and setting, $I_o = 0$, causes, hence, an increase in gamma, $\hat{\gamma}_1$, of the camera-tube transfer characteristic as illustrated in Fig. 12 by the operating characteristics of a camera tube with a normal gamma of 0.5.

3. *Kinescope Operating Characteristics*

Kinescope dynamic transfer characteristics obtained with picture modulation are constructed from the static transfer curve S (taken from published technical data for kinescope types in the *RCA Tube Handbook*) shown in Fig. 13, by adding the flare and ambient light bias, B_o, which is determined by optical conditions in tube and viewing room. A maximum measured screen contrast range, $C = 100$, for example, in a normal image furnishes $B_o = 0.01\hat{B}$ and the dynamic characteristic curve 0 in Fig. 13. The *operating characteristic* of the kinescope is a section of the dynamic characteristic and can be adjusted to a variety of values by the black signal level setting, E_o, at the receiver. The conditions, $E_o/\hat{E} = 0.05$ and 0.09, shown in Fig. 13, represent zero-signal settings close to subjective black. The corresponding operating characteristics are constructed by expanding the signal range, $\hat{E} - E_o$, of curve 0 to unity. The signal voltage E' for these corresponding operating characteristics are determined from:

$$E' = (E - E_o)/(\hat{E} - E_o) \qquad (12b)$$

For the range, $E_o/\hat{E} = 0.09$, and the signal voltage, $E = 0.14$ at point P, for example, Eq. (12b) furnishes the expanded value, $E' = 0.055$ for point P'. Figure 13 shows that kinescope operating characteristics have a lower maximum gamma, $\hat{\gamma} = 2.2$ to 2.3, than the original static characteristic, $\hat{\gamma} = 3$.

4. *Motion Picture Film Characteristics*

The transfer characteristics of Plus X negative film (5231) and type 5302 fine-grain release positive film are shown in Figs. 14 and 15.* The characteristics were measured with substantially parallel light on II B sensitometer step exposures. The developed films obtained from the Motion Picture Film Dept. of the Eastman Kodak Co., New York, N.Y., received standard motion picture processing (spray process on negative, deep tank on positive by DeLuxe Film Laboratories, New York, N.Y.).

5. *Over-All Transfer Characteristics*

The combination of several transfer characteristics in an imaging system results in a curved or S-shaped over-all characteristic. The characteristics of an image orthicon (Fig. 6) ($I_o = 0$) in combination with a linear amplifier and the kinescope transfer characteristics, $E_o/\hat{E} = 0.05$, of Fig. 13 furnish the curve family shown in Fig. 16. The parameter in this curve is the high-light exposure in the camera tube with respect to its "knee point." The values 1.2 to 7.2 represent a range of five lens stops. The optimum exposure for best tone quality and texture is near the value $\hat{E}_1/E_{knee} = 2$ (see Figs. 9a and 9b). Overexposures, 4.7 and higher, result in excessive electron flare (redistribution) and poor quality (see Figs. 8a and 8b); underexposures, 1 or less, result in loss of shadow detail.

* The exposure, E, is given in meter-candle seconds.

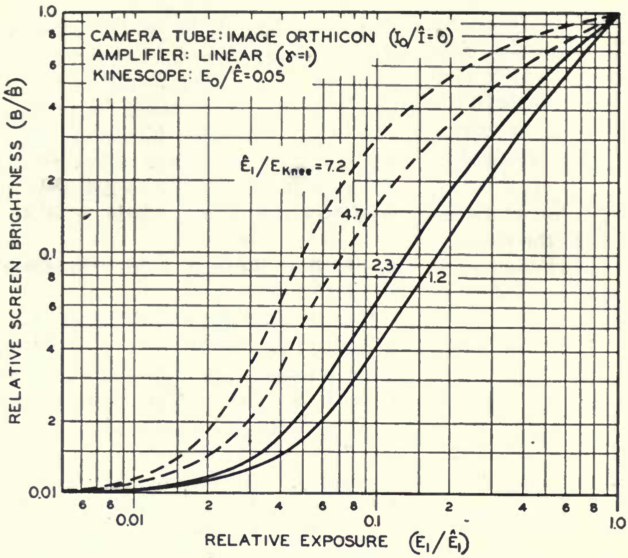


Fig. 16. Over-all transfer characteristics of a television system.

Adjustment of the black-level setting, E_o, at the kinescope changes its transfer characteristic (see Fig. 13) and, consequently, the gamma of the over-all transfer characteristic. The characteristics obtained with *linear amplifiers* and with the kinescope black-level setting, $E_o/\hat{E}$, as parameter are shown in Fig. 17 by the broken-line curves for an image signal source with linear transfer characteristic, $\gamma_1 = 1$, such as a light-spot scanner or orthicon (or British C.P.S. Emitron), and by the solid curves for normal exposure of an image orthicon. The characteristics for the linear signal source are identical with the kinescope operating characteristic and, because of the high gamma, $\gamma_{12} \simeq 2.2$, seriously compress tone rendition of scenes exceeding a 10 to 1 contrast range (blocked "blacks"). The image orthicon characteristics are much more acceptable because they permit reproduction of a scene having a contrast range of 40 to 1 with an over-all gamma of approximately 1.3 decreasing in the highlight and shadow tones. A natural-tone rendition (constant gamma) requires, therefore, a correction of the transfer characteristic. More specifically, reproduction of a scene having a contrast range of 100 to 1 and constant gamma requires an over-all gamma of unity.

The characteristic of a standard motion picture film process is shown in Fig. 18. The film characteristic, 0, is slightly *S*-shaped and the over-all system characteristic, curve 1 or 2, becomes more *S*-shaped because of the flare light bias from camera- and projection-lenses (½% for each) and the light bias due to ambient light on the projection screen (1%). A combination and a repetition of uncorrected television and motion picture processes result in a more serious compression of both shadow and highlight gradation as exemplified by the combination characteristics in Fig. 19.

It is evident that a normal projected 35-mm motion picture is not an ideal source for generating television signals and neither is it, as is well known, a good source for making a duplicate motion picture. It is common knowledge that a chain of separate amplifiers can remain linear with respect to trans-

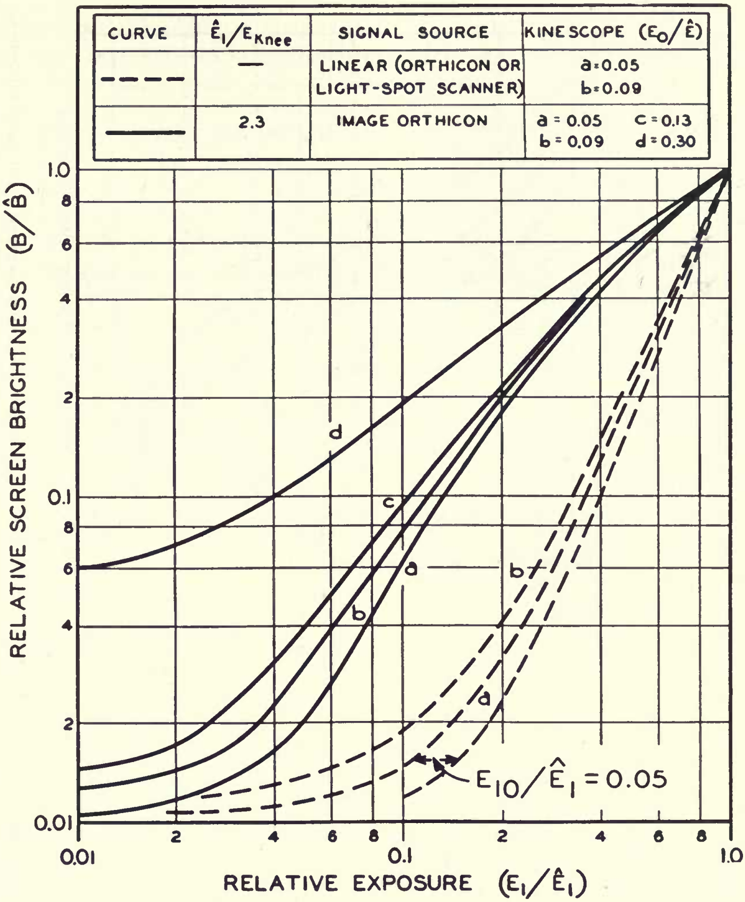


Fig. 17. Over-all transfer characteristics of television systems with image orthicon and linear signal sources.

fer and frequency characteristics when each amplifier has linear response characteristics. Such amplifiers can be cascaded without loss of quality. By the same principle, imaging processes with linear response characteristics can be cascaded without loss of quality. It is possible to correct errors in the frequency response and transfer characteristics, but the image signals must remain considerably above the fluctuation or "noise" level at all points of the system after passing through lenses, films, television tubes and amplifiers.

6. *Transfer Characteristics and Gamma of Motion Picture Film for TV*

The reproduction of images over a motion picture and television process involves a large number of transfer elements. Shape and contrast range of the transfer characteristic of a normal motion picture positive are adjusted to fit the optical conditions in direct theater projection. It is logical, therefore, that the characteristics of motion picture film intended as a picture source for reproduction by a television system or for storage and reproduction

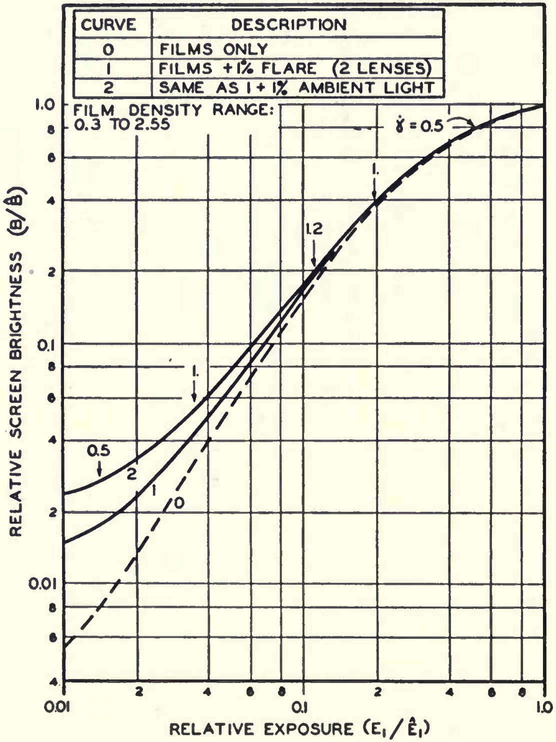


Fig. 18. Transfer characteristic of 35-mm motion picture process.

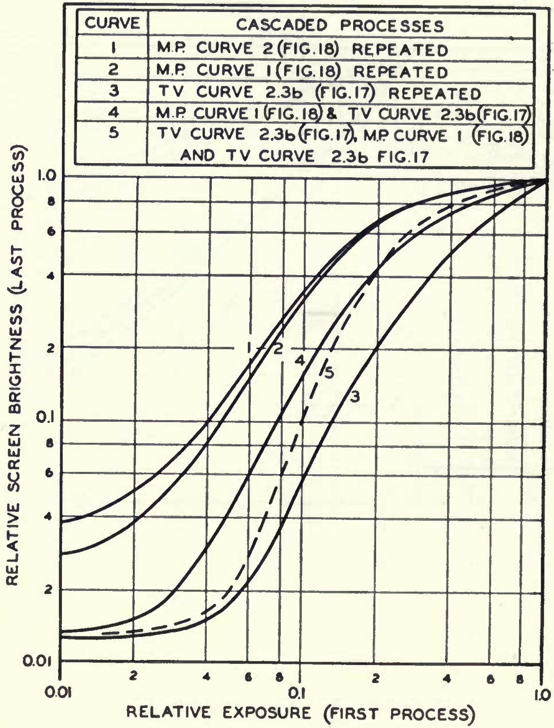


Fig. 19. Transfer characteristics of normal (uncorrected) imaging processes in cascade.

of video signals should be adjusted to fit the range and transfer characteristic of the television system and not the eye. The addition of one or several imaging processes increases the need for low distortion. The television process introduces as an important parameter an adjustable "black level" which, in effect, permits a subtraction of light levels and eliminates high densities in the positive film as a requirement. The "signal" levels in the system (contrast range) can be reduced to lower values to gain linearity of signal transfer as in electron tube amplifiers, but the signal must remain sufficiently large to prevent an increase of the fluctuation level (noise, treated in Part II).

The excessive distortion of the tone scale (see Fig. 19) resulting from an addition or a repetition of "normal" processes can be prevented by restricting the operating range on tube and film characteristics. With regard to the film process it is evident that operation in the constant-gamma sections of the film transfer characteristics results in uncritical exposure conditions and in over-all film characteristics with unity or constant gamma. Inspection of available film characteristics shows that the constant-gamma range of positive films in particular extends over hardly more than a 20 to 1 range in transmission. It is very desirable that films with a shorter toe and a longer constant-gamma range be developed for television purposes.

7. *Motion Picture Film for Television*

The graphic solution for the optimum density range and gamma of motion picture positive film for television is quite simple. Because it is advantageous to use a substantially linear amplifier, the density range of the positive film (controlled by the print gamma) should be adjusted to equal the optimum exposure range of the camera tube which can be determined from the over-all transfer characteristics such as those shown in Fig. 17. The exposure scale is adjusted by adding or subtracting a constant, E_{10}, to the exposure values. The constant is selected to obtain a characteristic with reasonably constant gamma. An image orthicon (curve 2.3a, Fig. 17) requires an additive constant, $E_{10}/\hat{E}_1 = 0.03$, i.e., an exposure contraction to a 25 to 1 range, while an orthicon type (Fig. 17), will give a more constant gamma with $E_{10}/\hat{E}_1 = 0.05$ and an exposure range of approximately 10 to 1. The density range, ΔD_2, in the positive film should thus have the values $\Delta D_2 \simeq 1.4$ for an image orthicon and $\Delta D_2 = 1$ for a linear camera tube such as the orthicon. Desirable motion picture film characteristics are shown in Table II.

Table II. Desirable Characteristics of Motion Picture Film for Television.

	Camera Tube			
	Iconoscope	Image Orthicon	Orthicon	Remarks
Camera exposure range	30 to 1	25 to 1	10 to 1	Linear amplifier
Positive Film				Constant gamma, short toe
Density range ΔD_2	1.6	1.4	1	Between shoulder and toe
Approximate gamma (γ_2) for negative $\Delta D_1 = 1.25$	1.28	1.12	0.8	for $\gamma_1 = 0.68$ Exposure range of neg. 100:1
for negative $\Delta D_1 = 0.95$	1.7	1.47	1.05	30:1

Fig. 20 is on plate page 169.

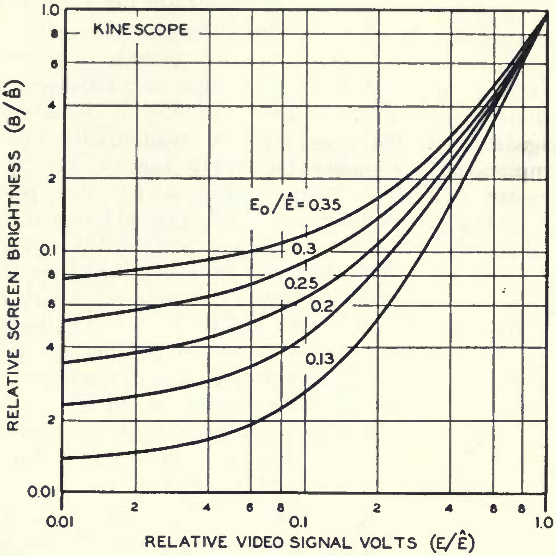


Fig. 21. Operating characteristics of kinescope with restricted signal range.

It is obvious that the specified density range, ΔD_2, in the positive print requires adjustment of the print gamma, γ_2, which depends on the density range of the negative which, in turn, is a function of negative exposure and brightness range in the camera image (100 to 1 and 30 to 1 for $\gamma_1 = 0.68$ in Table II). A 35-mm print of the SMPTE Television Test Negative on 5365 stock developed to a gamma of 0.95 gave excellent uniformity of levels and negligible "flare" when projected into an orthicon or image orthicon. The reproductions of the gray scale and tone values in the picture section were excellent (Fig. 20),* required no black expansion, and were far superior to those obtained with a normal high-gamma test film. Due to absence of distortion in the constant-gamma positive, however, black-level and signal range varied in accordance with variations in density and range in the negative, exceeding at times the exposure range of the orthicon. Reproduction of the film by an image orthicon with moderate exposure ($\hat{E}_1/E_{\text{knee}} = 1.2$) gave, therefore, the best results. The appearance of an optical projection of the low-gamma print is, of course, quite unsatisfactory.

The process of kinescope recording is, in principle, a process for storing and duplicating a video signal. Assuming a constant-gamma transfer of light values by the film process, it follows that the combination transfer characteristic of the recording kinescope, the film-scanning camera tube, and the video amplifier must likewise have a constant gamma to obtain an undistorted duplication of the original video signal. It has been shown that the adjustment of the operating point, E_o, on the kinescope characteristic is a means of varying contrast range and gamma of the kinescope and results in a family of characteristics shown in Fig. 21. The exposure range

* The arc line in the picture is a target flow in the camera tube.

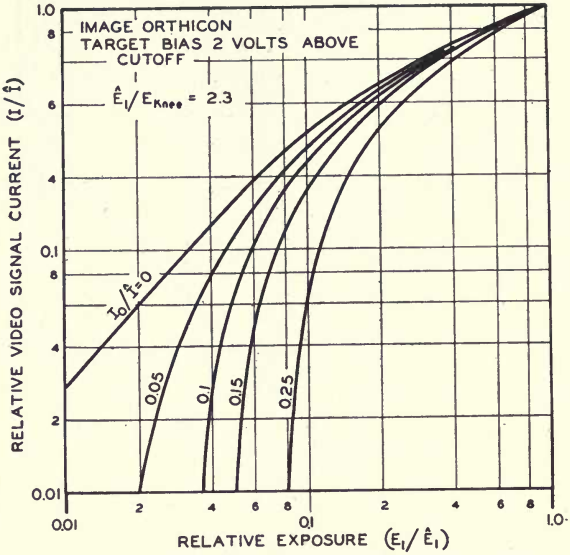


Fig. 22. Operating characteristics of image orthicon with restricted exposure range.

of the film and the following camera tube can thus be restricted to any desired value.

The light level representing zero video signal at the kinescope is a gray level on the positive film and results in a (d-c) signal-current level on the camera-tube characteristic below which the video signal will never decrease. This minimum signal level, I_o, represents, therefore, the black level in the video signal, and is set to zero at the transmitter by an operator adjustment. Restriction of the exposure range and resetting of the black level by subtraction of the minimum signal, I_o, from the transfer characteristic of the camera tube furnishes the family of operating characteristics as shown in Fig. 12 or as in Fig. 22 for an *image orthicon*. The method of constructing these characteristics has been explained above (see Eq. 12a).

After the curve families are plotted, the light range giving the best match of kinescope and camera-tube operating characteristics can be determined by rotating one of the curve sheets 180° around its diagonal and placing it over the other curves so that the scales for light values and electrical signal scales superimpose. For the example, the curves coinciding most accurately in shape are the kinescope curve, $E_o/\hat{E} =$ 0.3, and the camera-tube curve, $I_o/\hat{I} =$ 0.1. (It is permissible to twist* the coordinates slightly.) When equal video signal values are selected, the corresponding light values on the two characteristics plotted against each other furnish the required transfer characteristic for the motion picture process (Fig. 23), assuming that a linear video amplifier is used. Film characteristics approaching this characteristic can now be selected. For uncritical exposure conditions and processing, both negative and positive films should be developed to approximately equal and constant gammas. It will be shown in Part II that a higher negative gamma and short toes reduce the fluctuation (noise) level in the film process. The remaining error in the film *transfer characteristics* is to be eliminated by correcting the transfer characteristic of the video amplifier

* The angle of twist indicates the departure from unity gamma in the associated photographic process.

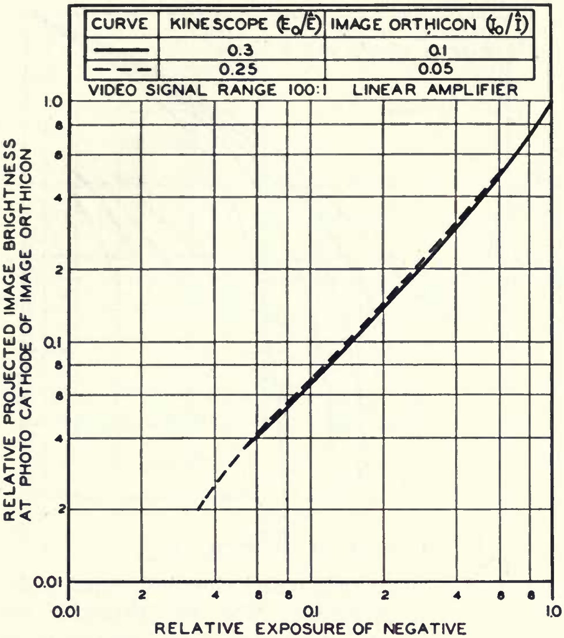


Fig. 23. Over-all transfer characteristic of motion picture process for reproduction of television recording with image orthicon.

preceding the kinescope or following the camera tube or both. Depending on the position in the chain (video signal–amplifier–kinescope–film process–camera tube–amplifier–video signal), the video correction characteristics differ. Correction of the amplifier driving the recording kinescope, for example, assumes that the video signal output values on the camera-tube characteristic and the video-input signals to the kinescope amplifier are equal. The amplifier output signal is thus found by tracing the camera signal over the light values in the film and kinescope characteristics back to the kinescope grid signal which equals the amplifier output signal. An electrical correction following the film process is more practical and has the advantage that the final image is under direct visual observation, permitting instantaneous adjustments for best results.

When an *iconoscope* is used as a film scanner the best compromise match of characteristics is obtained for $E_o/\hat{E} \simeq$ 0.3 at the kinescope and an averaged peak illumination, $\hat{E}_1$, in the order of 10 units (in Fig. 11) at the iconoscope mosaic. The gamma in the high-light range of the iconoscope, however, is too low, requiring considerable "white" expansion by a correction amplifier. This condition is amplified at higher peak exposures of the tube for which the kinescope bias decreases toward $E_o/\hat{E} = 0.2$. The operating conditions for a *linear film scanner* (orthicon, light-spot scanner) are evaluated similarly and furnish the transfer characteristics shown in Figs. 24a and 24b. The film characteristics are listed in Table III. Film characteristics for a camera tube with constant gamma, $\gamma_1 = 0.5$, are listed for comparison.

8. Effect of the Line Raster on Film Exposure and Sensitometry

Maximum detail contrast in kinescope images requires a scanning-beam diameter smaller than the pitch distance of the scanning or "raster" lines. (See

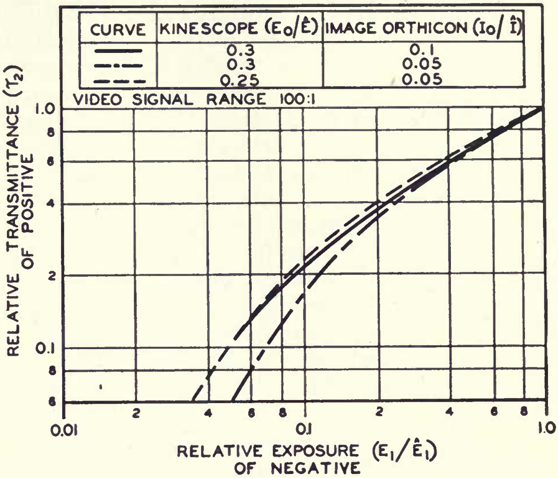


Fig. 24a. Over-all transfer characteristic of motion picture process for reproduction of television recording with linear camera tube.

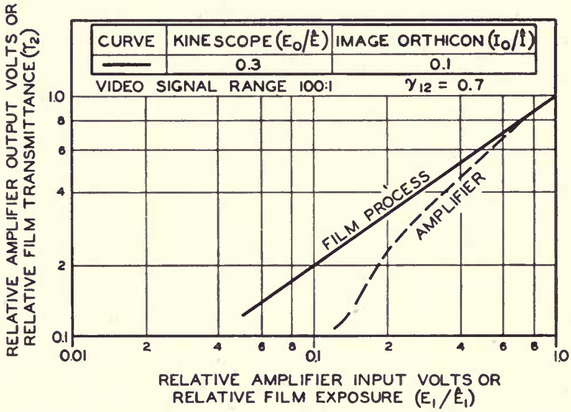


Fig. 24b. Transfer characteristics of film process and amplifier used in process of Fig. 24a.

Table III. Characteristics of Motion Picture Film For Video Recording.

	Camera Tube $\gamma_1 = 0.5$	Iconoscope	Image Orthicon	Orthicon $\gamma_1 = 1.0$	Remarks
Exposure range in negative	50:1	30:1	20:1	20:1	
Negative γ_1	0.875	1.0	1.0	1.0	Constant
Positive γ_2	1.25	1.25	1.1–1.2	0.7	Constant
Over-all γ_{12}	1.1	1.25*	1.1–1.2†	0.7‡	Constant
Density range in positive	1.6	1.85	1.4	0.9	

* Requires electrical expansion in the high-light range.
† See Fig. 23.
‡ See Fig. 24.

Reference 1 and Part III of this paper.) A kinescope beam defocused or vertically enlarged to produce a "flat" field has an equivalent rectangular cross section equal to the pitch distance of the raster lines. With a flat field a given brightness range in the kinescope image can be recorded on film with normal exposures. Normal sensitometric conditions are maintained also for the case in which a smaller scanning aperture produces a line structure on the kinescope which is not resolved by the combination of lens and negative film, resulting again in a flat field on the negative.*

An equivalent line cross section, smaller than the raster pitch distance, requires an increase of the kinescope *line brightness* by the ratio of pitch distance to line width in order to maintain a given image brightness. Hence, when a high-resolution kinescope is focused sharply and the dark spaces between raster lines are, for example, equal to the line width, the line intensity doubles. To record the increased line-brightness values within the normal range on the film transfer characteristic, the exposure of negative film with adequate resolution (for example on a 4 × 5 in. film) must be reduced to one-half the value found normal for a flat field (defocused case). The negative is given a normal development but will appear underexposed, because part of the film area remained unexposed by the black raster spaces. For a perfectly sharp recording, the minimum transmittance ($\bar{\tau}_{min}$) of the negative cannot be expected to decrease below the theoretical value:

$$\bar{\tau}_{min} = \text{(pitch distance)} - \text{(equivalent line width)}$$

Measurement of true line-density values, D or D_{max}, requires use of a microdensitometer to read an area within the line cross section.

Printing of a sharp line raster negative with normal line densities on a positive film requires a normal exposure, but the "weighted" transmittance of the positive cannot exceed the maximum value:

$$\bar{\tau}_{max} = \text{(pitch distance)} - \text{(equivalent line width)}$$

irrespective of the resolution of this process. Projection of the positive requires a higher film illumination, but contrast range and over-all transfer characteristic are normal. A print on paper, however, results in a reduced contrast range because of the unchanged "black" limit of the paper. High lights are "gray" due to light transmission and exposure through the clear spaces separating the exposed raster lines in the negative. In practice, neither kinescopes, lenses nor negative film can maintain perfect contrast between raster lines and "black" spaces throughout the tone range. Practical "resolving apertures" (see Section A) have a nonuniform light distribution which causes a gradual change of light intensity and exposure between line centers. Test exposures on 4 × 5 Super XX Film made with a defocused kinescope spot and, subsequently, with a sharply focused spot approximately ½ line-pitch in diameter, have shown that an exposure reduction by a factor of two for the sharp-line negative resulted in a slightly higher density of the scanning lines and a "weighted" density range of 0.19 to 1.0; the density range of the defocused negative was 0.3 to 1.2. The two negatives received identical processing. Contact positives were made by printing both negatives side by side on one sheet of film. The weighted densities, $\bar{D}$, of the fine-line positive were higher by $\Delta D \simeq 0.3$ (due to the black spaces between lines). With correspondingly adjusted illumination, the tone scales of the two positives

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* It is noted that a "flat" field requires a constant spot diameter and perfect uniformity of line spacing, conditions which are difficult to realize with rasters containing 500 or more lines. The effects on resolution will be discussed in Part III.

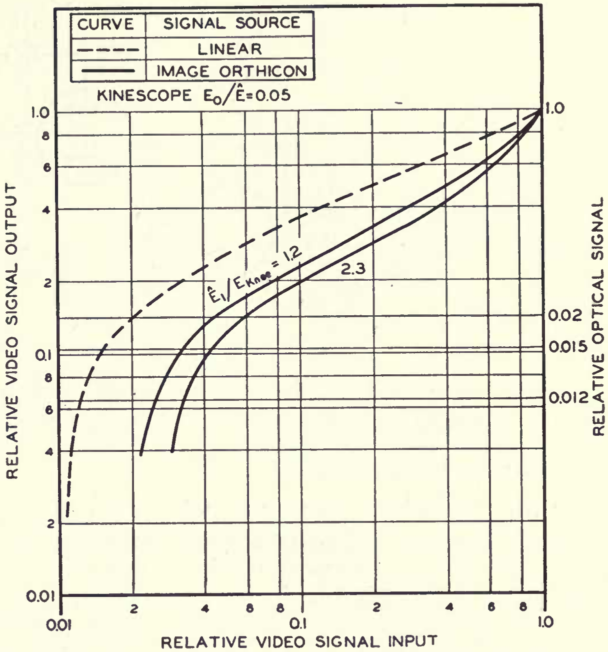


Fig. 25. Transfer characteristics of gamma-correction amplifier providing over-all gamma of unity.

were substantially the same at a normal viewing distance, the fine-line positive being preferable for its sharpness. *The effective transfer characteristic* of an imaging process transducing a raster image with a nonuniform intensity distribution over the line cross section is actually a *weighted transfer characteristic extending over a greater range of signal values.* The practical equivalent for particular cases is best determined by measurement.

Experience with photography of sharp kinescope images substantiates the requirement of a transfer characteristic with a somewhat longer range or, as pointed out above, a reduction of the kinescope brightness range (raised black level).

9. Gamma Correction in Television Systems

The point gamma values in the over-all transfer characteristic are the product of the respective point gammas of all component characteristics. A low gamma value in one element can, therefore, be corrected by a high (reciprocal) gamma value in another element. A distorted over-all response characteristic can be made linear by a response characteristic having reciprocal point gamma values. Gamma correction characteristics for several normal television system characteristics are shown in Fig. 25. The characteristics are constructed by selecting equal light values for input and output of the system and plotting the corresponding camera-tube output signal (input to the amplifier) versus the input signal (output of the amplifier) of the kinescope. (A scale indicates corresponding optical signal values.)

The transfer characteristics of a video amplifier can, in principle, be modified by the use of nonlinear circuit elements to have any desired shape. Curved transfer characteristics can be obtained by utilizing the normal curvature of one or several electron tubes in parallel or in series. Greater curvatures can be produced by nonlinear resistances such

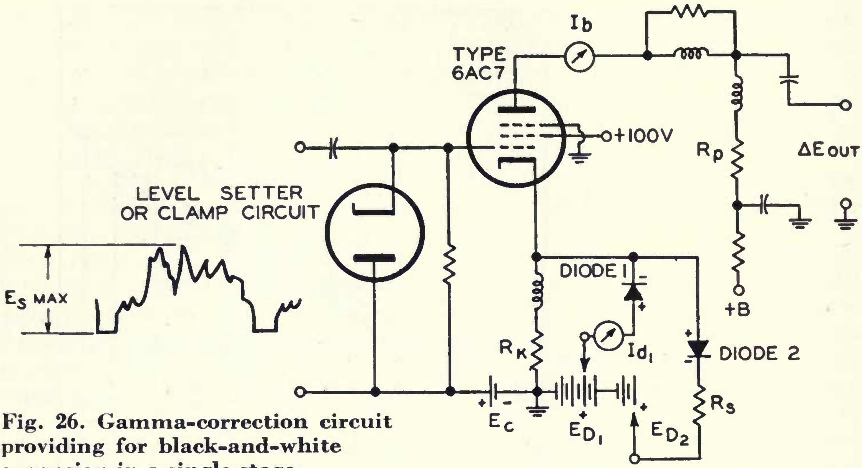


Fig. 26. Gamma-correction circuit providing for black-and-white expansion in a single stage.

as diodes or triodes in combination with resistors, employed as load resistances in current-carrying electrodes of electron tubes. A circuit permitting the correction of single curvature as well as *S*-shape characteristics in one amplifier stage is shown in Fig. 26. This circuit has a relatively low insertion loss because the nonlinear elements are located in the cathode circuit of the amplifier permitting the use of compensated high-impedance plate loads which must remain constant. The voltage gain of such a correction stage for a linear signal source is in the order of 0.75 for a 20-mc channel* and proportionally higher for lower passbands. The larger signal voltages required for correcting strong curvatures are handled easily by a small amplifier tube (6AC7).

At zero signal input, diode 1 (black expander) of Fig. 26 is made to conduct a current the value of which is determined by the voltage, E_{D_1}. The diode impedance shunts the cathode resistor, R_k, with a relatively low value; the amplifier gain is high. When the amplitude of the signal current equals the initial diode current, diode 1 becomes an open circuit and the amplifier gain is degenerated to a lower level determined by R_k. At higher signal amplitudes the cathode potential rises and finally diode 2 (white expander) conducts, shunting R_k by its impedance (adjustable by R_s), and thus increases again the amplifier gain. The graphic construction of the transfer characteristic from the conductance characteristics of the cathode circuit elements is illustrated by Fig. 27 for the case in which the amplifier stage also performs the function of a black-level clipper. The current-voltage characteristic, I_k vs. E_k, of the cathode circuit results from simple addition of the currents of the parallel elements (vertical addition of curves R_k, D_1 and D_2); the series characteristic, I_k vs. E_s, for tube and cathode circuit results from (horizontal) addition of the grid-to-cathode voltage, E_{GK}, of the tube and the cathode-to-ground voltage, E_k, of the circuit. The transfer characteristic, I_b vs. E_s, of plate current versus signal input voltage, E_s, is finally obtained by subtracting the screen-grid current from corresponding cathode-current values.

The graphic determination of the circuit constants required for a given gamma correction (broken-line curve, Fig. 25) is illustrated in Figs. 28a, 28b

* This type of circuit has been in use by the author for many years.

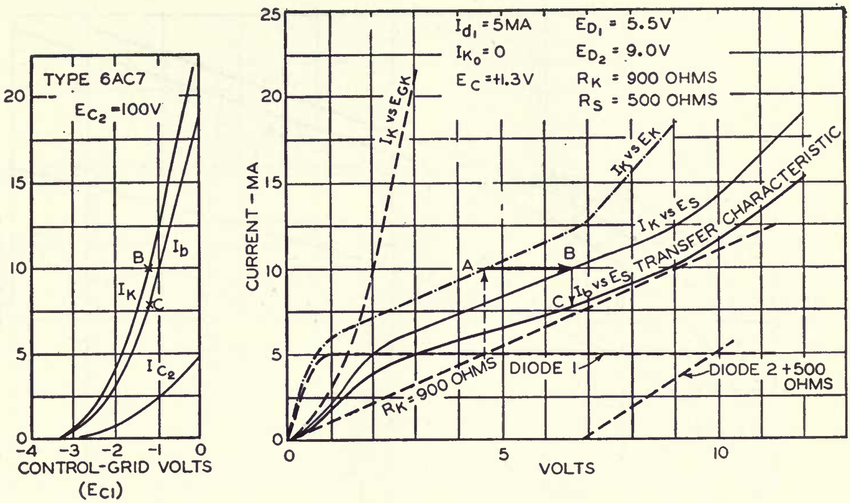


Fig. 27. Graphic construction of transfer characteristic of gamma-correction circuit (Fig. 26).

and 28c. Plate and cathode current for the amplifier tube (6AC7) are drawn in linear coordinates. When a zero-signal plate-current value (I_{b_o} = 6 ma for the example) is selected, the desired plate current versus signal characteristic, I_b vs. E_s, is drawn with a current range (6 to 16 ma) within the range of the tube. The voltage range is selected to avoid a crossover with the tube characteristic, I_b, as shown in Fig. 28a.* The characteristic, I_k vs. E_s, is now constructed by adding the screen-current values, I_{c2}, corresponding to the plate currents, I_b. Subtraction of the grid-cathode voltage, E_{GK}, (horizontally) from this curve results in the cathode network characteristic, I_k vs. E_k. A line drawn tangent to this curve furnishes the value of the cathode resistance load, R_k (1450 ohms). The load, R_k, intersects the current axis at E_s = 0 and a current value, I_{Rk}, equal to the total current in R_k at zero signal (13.5 ma). The voltage, E_k, between cathode and ground follows from Ohm's law (E_k = 1450 × 0.0135 = +19.6 v). The difference in current, $I_{Rk} - I_k$, as a function of E_k is plotted by subtracting the curve, I_k vs. E_k, from the R_k characteristic. It represents the required diode circuit characteristic, I_d vs. E_d (Fig. 28b). This characteristic is now broken up into sections which can be obtained with available diodes. Figure 28b shows the component curves D_1, D_2, D_3, which can be obtained with germanium diodes and series resistances (Fig. 28c). The zero-signal diode currents (1.9, 1.0 and 3.4 ma) are obtained from the curves as well as the diode biasing voltages which exceed E_k (19.6 v) by the voltage drop of the diode characteristics D_1, D_2, D_3. For the example, the diode bias potentials are: E_{D_1} = +20.2 v, E_{D_2} = +21.1 v, and E_{D_3} = 23 v.

The curve, I_d vs. E_d, can be approximated with two diodes, but it is cautioned that too sharp a break in a transfer characteristic may cause a "quantizing" effect, which is a spurious contour at gradation values corresponding to the break point.

The diagram of a practical gamma-correction circuit with adjustable black-and-white expansion is shown in Fig.

* A lower voltage range will be found to require an amplifier tube having a steeper plate-current characteristic than shown.

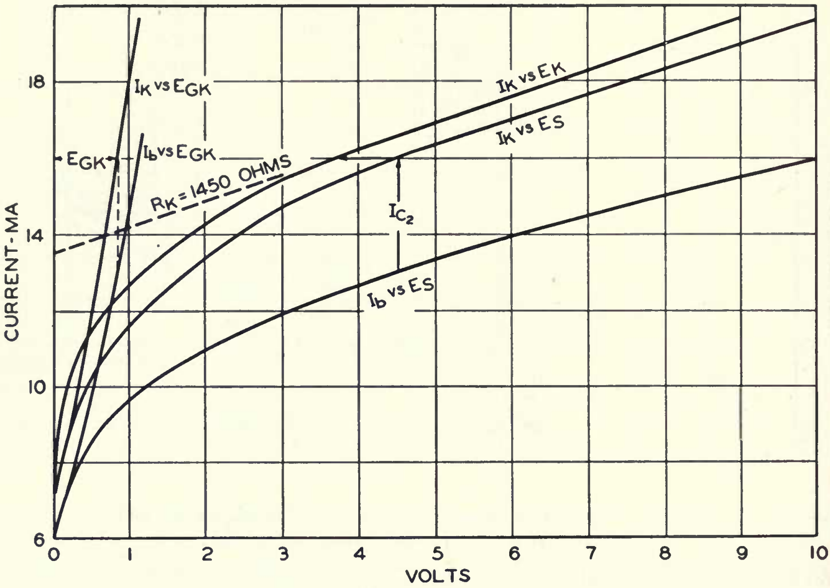


Figure 28a.

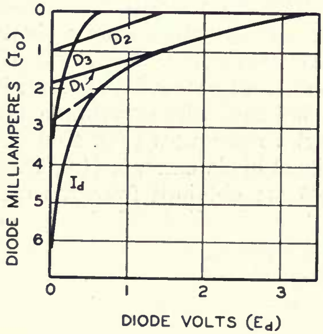


Figure 28b.

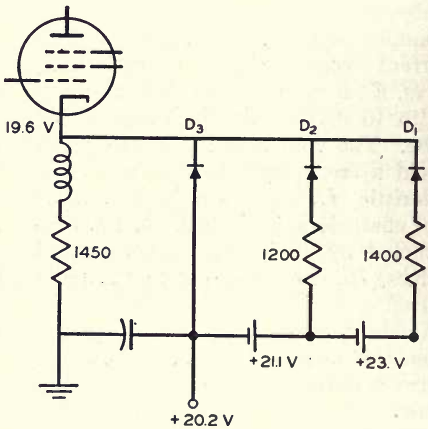


Figure 28c.

Fig. 28. Graphic determination of circuit constants required for a given gamma correction.

29. It is essential to maintain a constant operating point, I_{b_0}, on the tube characteristic by a level setter which establishes a fixed operating bias for the tube. The bias voltages for the black-expansion diodes, D_1, D_2, D_3, are obtained from a tapped bleeder circuit in which a heavy bleeder current maintains substantially constant potentials with varying diode currents. The black-expansion control changes the diode bias values in proportion, main-

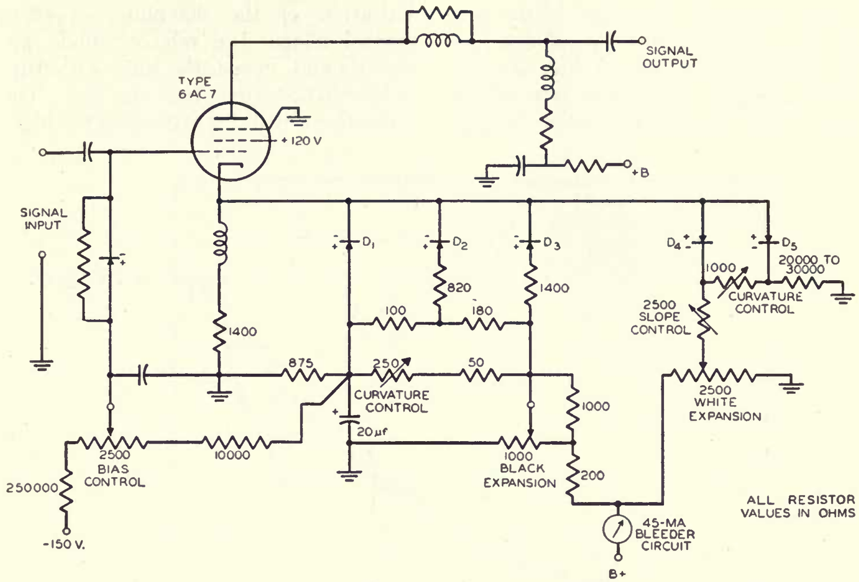


Fig. 29. Gamma-correction circuit with adjustable black-and-white expansion.

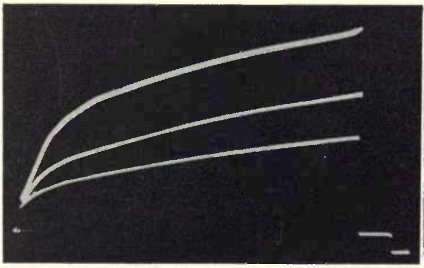


Fig. 30. Oscillograms of transfer characteristics for various settings of black expansion control in Fig. 29.

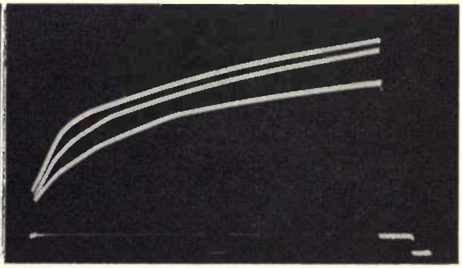


Fig. 31. Oscillograms of transfer characteristics for various settings of curvature control in Fig. 29.

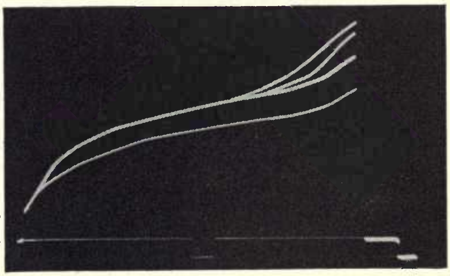


Fig. 32. Oscillograms of transfer characteristics with black-and-white expansion obtained with Fig. 29.

taining a smooth curvature of the correction characteristic as shown by the oscillograms given in Fig. 30 (obtained with a linear sawtooth-voltage input to a similar correction stage). Variation of the 250-ohm curvature control affects the relative diode potentials and, hence, the knee curvature of the characteristic (see Fig. 31). The correction circuit for expanding the high-

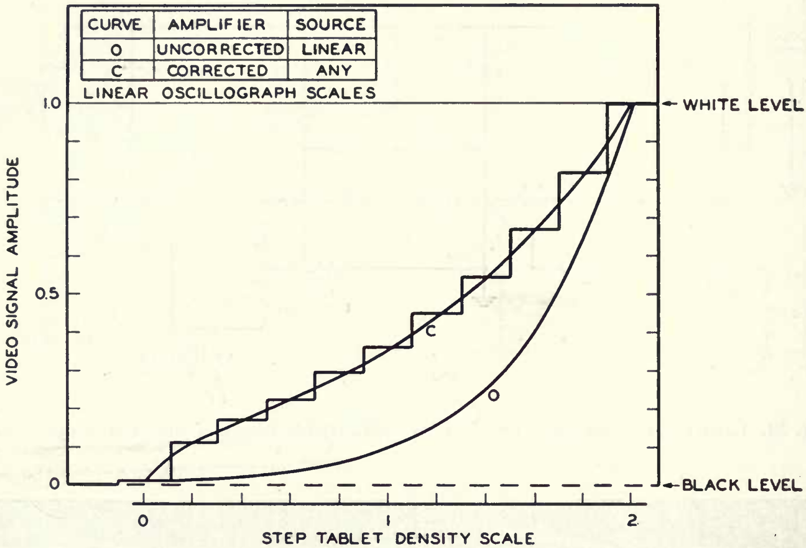


Fig. 33. Transfer curves of camera tube and video amplifier in semilog coordinates, showing an uncorrected characteristic, 0, and characteristic, C, with proper correction.

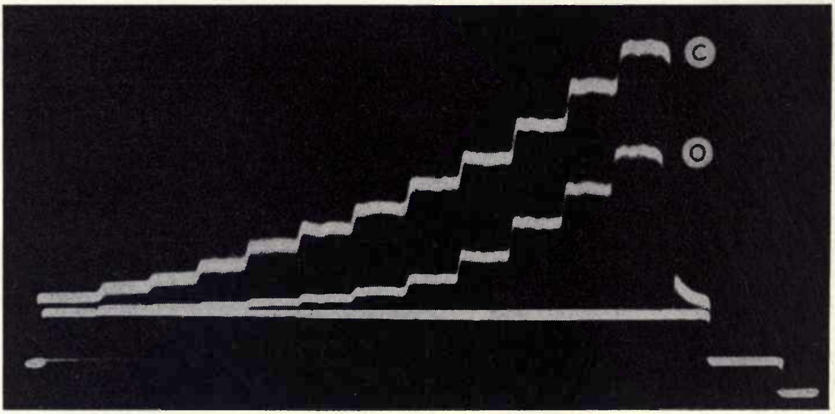


Fig. 34. Oscillograms of transfer characteristics of light-spot scanner (linear) and video amplifier with correction, C, and without correction, 0. Step tablet density range $\Delta D = 2$.

light range (reversed diodes D_4 and D_5) is similarly adjustable. The setting of the white expansion control determines the point at which the gamma starts to increase and the slope control determines the desired increase of the point gamma. The high-light diode circuit operates normally with small average currents and does not require a heavy bleeder current to obtain stable potentials. The oscillograms given in Fig. 32 illustrate characteristics with black-and-white expansion.

A practical method for adjusting gamma-correction stages is the observation with an oscilloscope of the signal from a logarithmic step tablet. A linear transfer of signals between the point of observation and the kinescope control grid and a linear over-all transfer characteristic require a characteristic of voltage versus light input which is the inverse of the kinescope characteristic. When the light input is changed logarithmically along a cross section of the picture, the linear oscilloscope time base represents a log-scale. The oscillogram of the step tablet is, hence, a semi-log plot of the corrected camera transfer characteristic which, for unity over-all gamma, must be the inverse of the kinescope characteristic regardless of the type of camera tube or signal source used. The gamma-correction stage is, hence, adjusted to obtain the transfer curve, C, shown in Fig. 33. (Note the upward curvature of the steps.) The oscillogram obtained with linear amplifiers from a linear signal source (light-spot scanner or orthicon) is shown for comparison. Actual oscillograms for these cases are given in Fig. 34.

The effectiveness of gamma correction in the amplifier is demonstrated by comparing the photographs given in Figs. 35 and 36. The photographs,

Fig. 20. Television reproduction of 35-mm motion picture frame from special low-gamma SMPTE test film. Bandwidth = 10 megacycles; scanning lines = 525; interlaced 2:1.

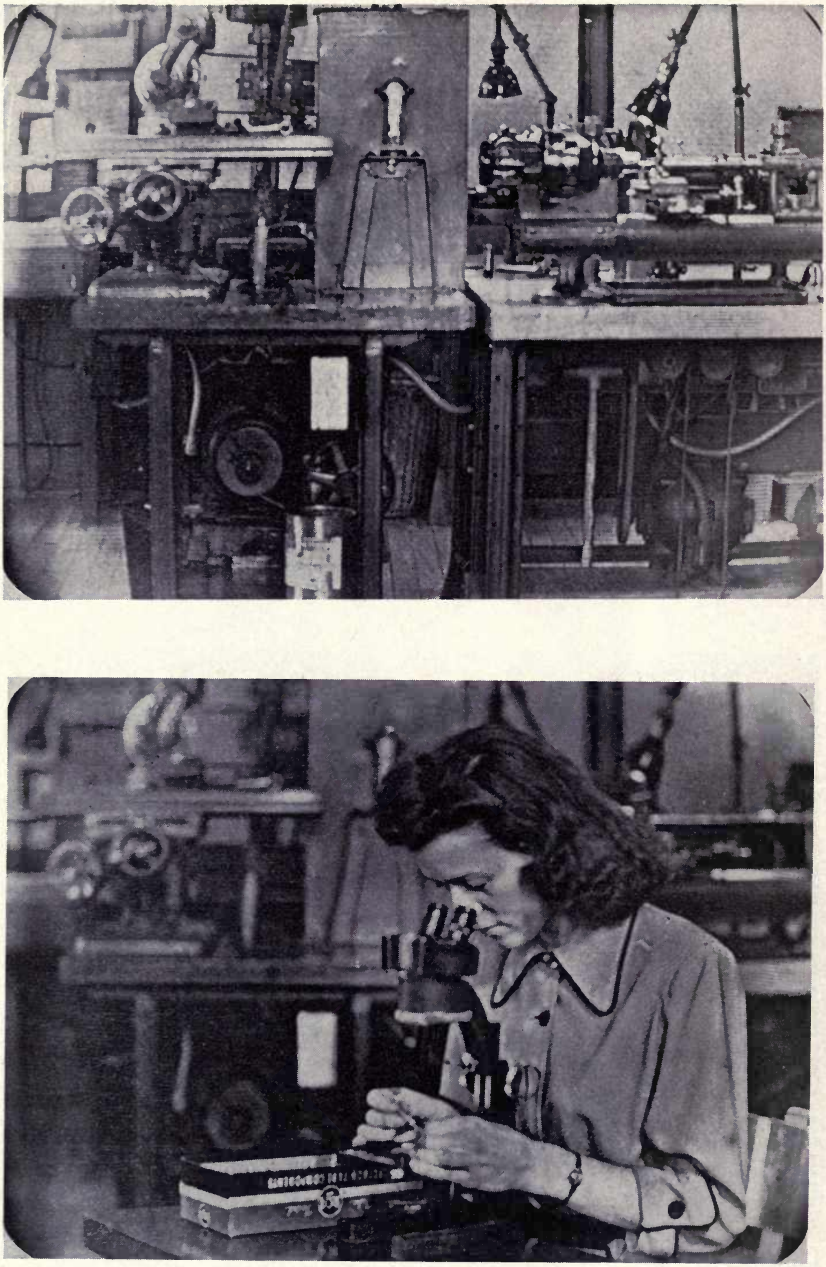


Fig. 8a, b. Poor quality television picture caused by over-exposure of image orthicon. Bandwidth = 4.25 megacycles; scanning lines = 525; interlaced 2:1.

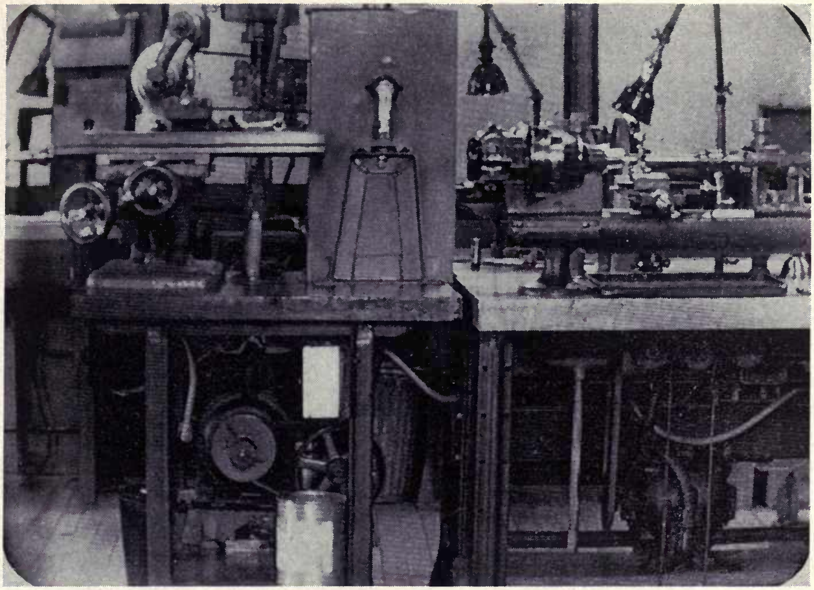
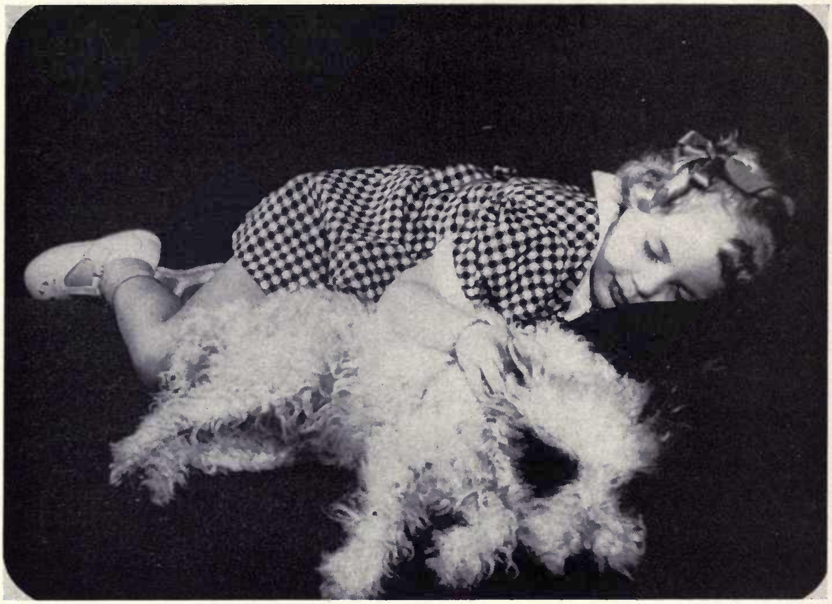


Fig. 9a, b. Good quality television picture obtained with proper exposure of image orthicon. Bandwidth = 4.25 megacycles; scanning lines = 525; interlaced 2:1.



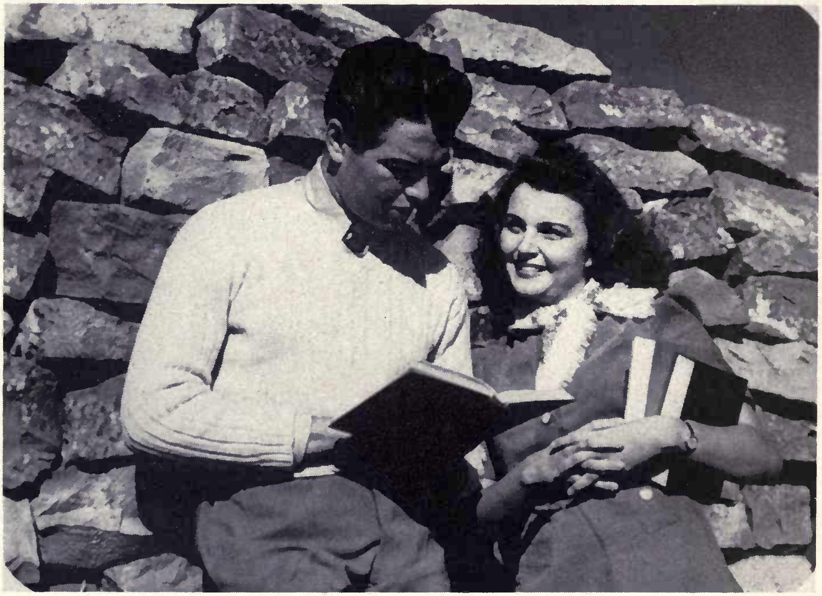


Fig. 35a, b. Photograph of optically projected 2 × 2 in. slide.

Fig. 36a, b. Photograph of television reproduction of 2 × 2 in. slide; light-spot scanner with gamma correction. Bandwidth = 4.25 megacycles; scanning lines = 525; interlaced 2:1.

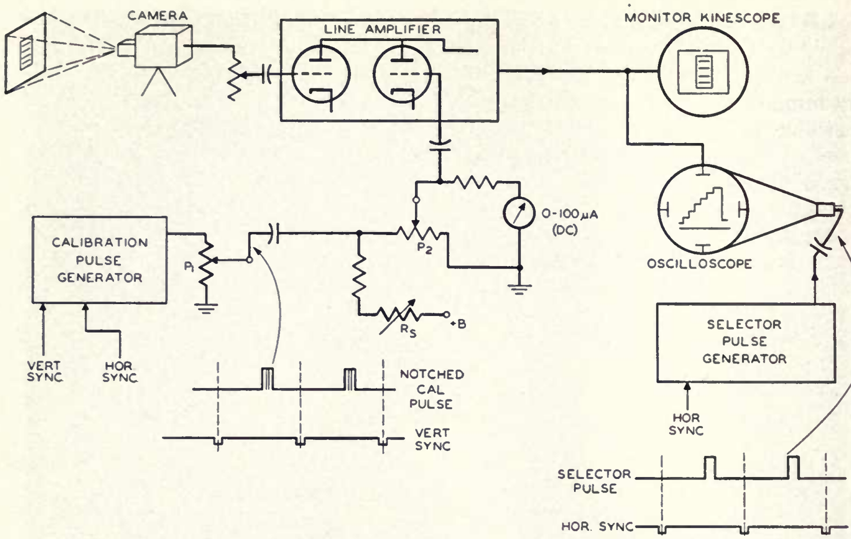


Fig. 37. Block diagram of vertical-cross-section selector and signal-measuring system.

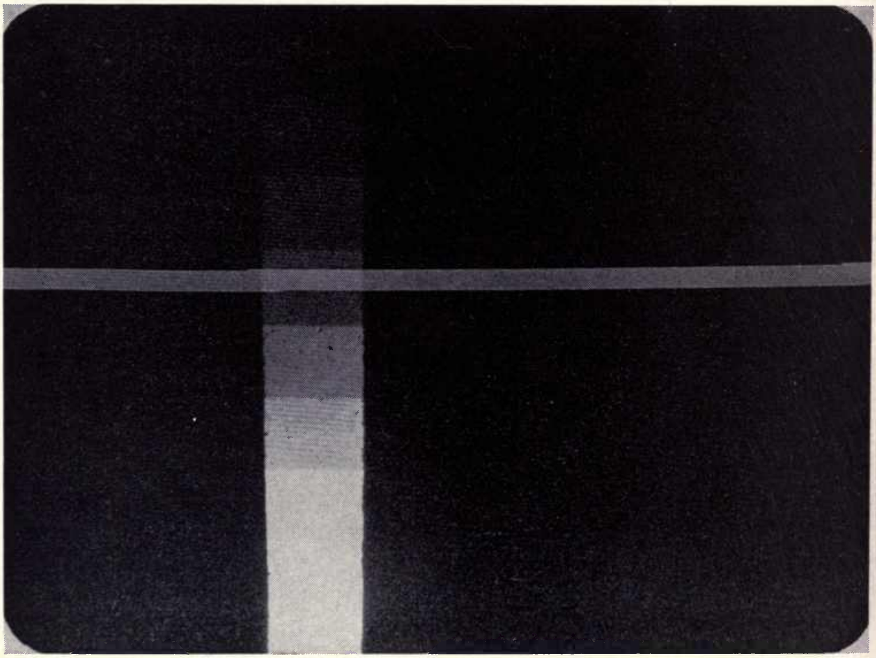


Fig. 38. Step tablet and calibration pulse on kinescope screen.

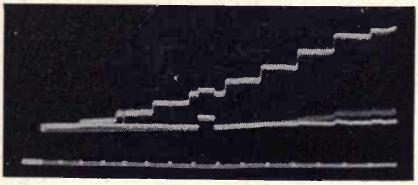
Figs. 35a and 35b, were made of a direct optical projection (coated lens, Kodaslide Projector Model 24) of two excellent miniature slides (obtained from the Eastman Kodak Co.) on a matte paper screen. The television reproductions, Figs. 36a and 36b, made with a corrected light-spot scanner of the same slides, are photographs of a 16-in., 525-line kinescope image reproduced over a standard 4.25-mc television channel. A negative film size of 4 × 5 in. and a 1.5-sec time exposure at $f/16$ minimize deterioration of image sharpness by the photographic process which was identical in both cases.

It is cautioned that the correction of transfer characteristics is accompanied by a change of the "noise"-to-signal ratio proportional to the gamma ($\dot{\gamma}$) of the correction characteristic. The subjects of random fluctuations in the television and photographic processes as well as resolution and detail contrast will be discussed in Parts II and III of this paper.

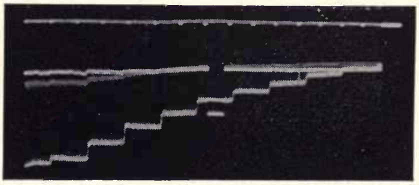
APPENDIX

1. Measurement of Camera-Tube Transfer Characteristics

An illuminated step tablet covering a range of 100 to 1 in ten equal logarithmic steps ($\Delta D = 0.2$) is placed vertically in the viewing field of the camera. The magnification is adjusted for a step size of 5 to 10% of the picture width on the kinescope. A vertical cross section of the step signal is obtained on an oscilloscope operated with a 60-cycle linear time base by applying to the oscilloscope control grid a positive horizontal pulse voltage of 5 to 10% of the line duration, timed by a double line frequency pulse to occur in the center of the field. The strip image from the camera is displaced horizontally against the vertical cross section selected by the pulse so that part of a uniform background adjacent to the step tablet produces a reference level signal on the oscilloscope (see Fig. 34). Depending on the background along the step tablet, the reference signal represents a black, white or gray level against which the step signals are measured. To eliminate errors due to amplifier nonlinearity and to permit expansion of small signals, the step signals are measured by a substitution method. A "notched" calibration pulse, several scanning lines wide, repeating at 60 cycles/sec is superimposed on the low-level signal from the camera (Fig. 37). It appears on the kinescope as a horizontal strip (see Fig. 38) which can be made to pass over any step of the tablet by vertical displacement of the tablet or its image (panning). The calibration pulse displaces a section of the oscillograph trace vertically (Fig. 39) permitting it to "lift" or depress (when of opposite polarity) a section of the reference level into the step level. The signal difference is thus equal to the pulse voltage. A convenient method



a. Partial displacement.



b. Pulse amplitude equal to step signal.

Fig. 39. Oscillogram of step tablet and superimposed calibration pulse.

for reading the relative calibration pulse voltage is indicated in Fig. 37. Potentiometer P_2 (200 ohms) is a voltage divider for the pulse voltage and an auxiliary d-c voltage which is adjusted by the series resistance, R_s, to give full-scale deflection on a d-c meter (0–100 μa) when P_2 is set for maximum output. With the selector pulse superimposed on the highest step level from the reference signal line, the maximum pulse signal lifting the reference level into the step level is set by potentiometer P_1. All other levels are then matched by adjusting P_2 and the d-c meter reads directly the relative step intensities.

Signal increments for adjacent steps can be measured by the same method. It must be considered, however, that redistribution, flare or edge effects in camera tubes can tilt the step signals.* The measurement of signals with respect to an adjacent level representing a constant light value at the source is, therefore, less likely to introduce errors because it is independent of shading. The characteristics of the image orthicon (Fig. 6) were measured by this method. Target bias values of less than 2 v result in widely different characteristics for dark and light backgrounds (see references 1 and 3) when it is attempted to cover a large light range.

2. *Operation Requirements for Systems With Gamma-Correction Amplifiers*

(a) Black-level variations are amplified. The controlling operator must be able to observe the corrected video signal.

(b) The signal gain between camera and correcting circuit should remain fixed once it is adjusted to give the correct relation between transfer characteristics. Adjustment of signal amplitudes from camera tubes with nonlinear characteristics should be made by controlling the exposure (mechanical or electronic shutter, iris, or neutral filters).

(c) Special effects requiring resetting of exposure, gain, or correction as well as equalization of a bank of cameras, may require a separate quality-control position. In this case, the camera video man exercises control over electrical focus, beam current and shading. He should see the corrected picture and may control target bias according to instructions from the quality-control operator.

(d) Expanded sections of the tone scale have a higher "noise" level, and compressed sections have a lower noise level. (See Part II.) A normal corrected tone scale results, in most cases, in a lower average brightness of the image than that obtained by overexposure of the image orthicon, although the highlight brightness is held constant. There may be a tendency to increase the picture brightness by increasing the signal amplitude to the kinescope, which results in higher visibility of fluctuations (noise).

The British and other European television systems operating with a 50-cycle frame frequency are limited by flicker to an image brightness which is lower by a factor of six to ten in comparison with American standards. A low picture brightness lowers the threshold of the eye for observing fine detail and fluctuations giving, therefore, the impression of a higher quality level.

3. *Calculation of the Average Number of Quanta in One Lumen of White Light*

The ratio of the luminous flux, F, to the radiated flux, P, within given wavelength limits, $\Delta\lambda$, is usually expressed in lumens per watt (lm/w):

$$(F/P)_{(\Delta\lambda)} = 680\ \overline{(Y_l Y_r)}_{(\Delta\lambda)}\text{lm/w}$$

where Y_l = relative luminosity factor
Y_r = relative energy factor of source
$\overline{(Y_l Y_r)}_{(\Delta\lambda)}$ = average value of products in the range $\Delta\lambda$.

* See Reference 1, Part IV, Fig. 81.

The factors, Y_l and Y_r, are unity at the reference wavelength, $\lambda = 0.555\ \mu$. The radiant energy giving one lm of light within the limits, $\Delta\lambda$, is hence:

$$P_{(\Delta\lambda)} = 0.00147/\overline{(Y_l Y_r)}_{\Delta\lambda} = 1.47 \times 10^4/\overline{(Y_l Y_r)}_{(\Delta\lambda)} \text{ ergs/sec}$$

The energy per quantum is the product of Planck's constant:

$$h = 6.547 \times 10^{-27} \text{ ergs/sec}$$

and the frequency of the light $\nu = 3 \times 10^{14}/\lambda$ (λ in microns):

$$h\nu = 19.641 \times 10^{-13}/\lambda \text{ ergs/sec}$$

Expressed with respect to the reference wavelength $\lambda = 0.555$:

$$h\nu = 3.54 \times 10^{-12}\,(0.555/\lambda)$$

where $(0.555/\lambda)$ is the relative energy factor.

The number of quanta in the radiated energy yielding one lumen of light is hence:

$$n_{r(\Delta\lambda)} = (P/h\nu)_{(\Delta\lambda)} = (1.47 \times 10^4/3.54 \times 10^{-12})/\overline{\left(Y_l Y_r \frac{0.555}{\lambda}\right)}_{(\Delta\lambda)}$$

$$n_{r(\Delta\lambda)} = 4.16 \times 10^{15}/\overline{\left((Y_l\, Y_r \frac{0.555}{\lambda}\right)}_{(\Delta\lambda)} \text{ quanta/lm}$$

where the bracketed term is the average product of the relative energy factors over the range, $\Delta\lambda$. For noon sunlight or a black body at 5400 K and the limits $\lambda = 0.40$ to $0.73\ \mu$, the above equation gives the quantum number:

$$n_{r(\Delta\lambda)} \simeq 1.3 \times 10^{16} \text{ quanta/lm}$$

References

1. O. H. Schade, "Electro-optical characteristics of television systems: Introduction," *RCA Rev.*, vol. IX, no. 1, pp. 5–13, Mar. 1948.
   "Part I — Characteristics of vision and visual systems," *ibid.*, pp. 13–37, Mar. 1948.
   "Part II — Electro-optical specifications for television systems," *ibid.*, no. 2, pp. 245–286, June 1948.
   "Part III — Electro-optical characteristics of camera systems," *ibid.*, no. 3, pp. 490–530, Sept. 1948.
   "Part IV — Correlation and evaluation of electro-optical characteristics of imaging systems," *ibid.*, no. 4, pp. 653–686, Dec. 1948.
2. P. K. Weimer, S. V. Forgue and R. R. Goodrich, "The Vidicon photoconductive camera tube," *Electronics*, vol. 23, no. 5, pp. 70–73, May 1950.
3. R. B. Janes and A. A. Rotow, "Light transfer characteristics of image orthicons," *RCA Rev.*, vol. XI, no. 3, pp. 364–376, Sept. 1950.

Technical Activities of the Motion Picture Research Council

By W. F. Kelley and W. V. Wolfe

A brief description is provided for the more important technical activities, including work in progress on composite photography, lighting equipment, wind machines, strippable adhesives, transportation equipment, plastics, diffusion cloths and other items of interest in the production of motion pictures. Mention is also made of the Research Council's function in connection with new products, inventions, television, stereoscopic motion pictures, standards and test films.

Although the history and functions of the Motion Picture Research Council were covered in an earlier paper before this Society,[1] it seems desirable to review briefly that information.

Originally, there was formed about 1928 the Technical Bureau of the Academy of Motion Picture Arts and Sciences. In 1932 the name, along with some of its functions, was changed, forming the Research Council of the Academy of Motion Picture Arts and Sciences. For fifteen years the Research Council existed largely as a secretariat relying upon voluntary services of studio and equipment manufacturers' personnel for most of the work carried on.

By 1947 it was freely recognized that insofar as methods, processes and equipment are concerned, there was no need for competition among the producers of motion pictures. Accordingly, it was practical to carry on the development of such equipment, processes and methods in a common industry-sponsored technical organization. With this end in view, the Motion Picture Research Council was separated from the Academy of Motion Picture Arts and Sciences and incorporated under the laws of the State of California. Funds and facilities were made available and the business of organizing a staff of qualified technical people and securing for them the necessary equipment and quarters was undertaken.

The Research Council is interested in any and all technical problems in the production or exhibition of motion pictures. In general, the activities can be divided into three groups: service functions, short-range development and design problems, and long-range advanced development problems. The staff includes two physicists, three chemists, two mechanical engineers, two electrical engineers and supporting personnel.

Figure 1 shows the large half of the mechanical and electrical laboratory

Presented on October 19, 1950, at the Society's Convention at Lake Placid, N. Y., by W. F. Kelley and W. V. Wolfe, Motion Picture Research Council, Inc., 1421 N. Western Ave., Hollywood 27, Calif.

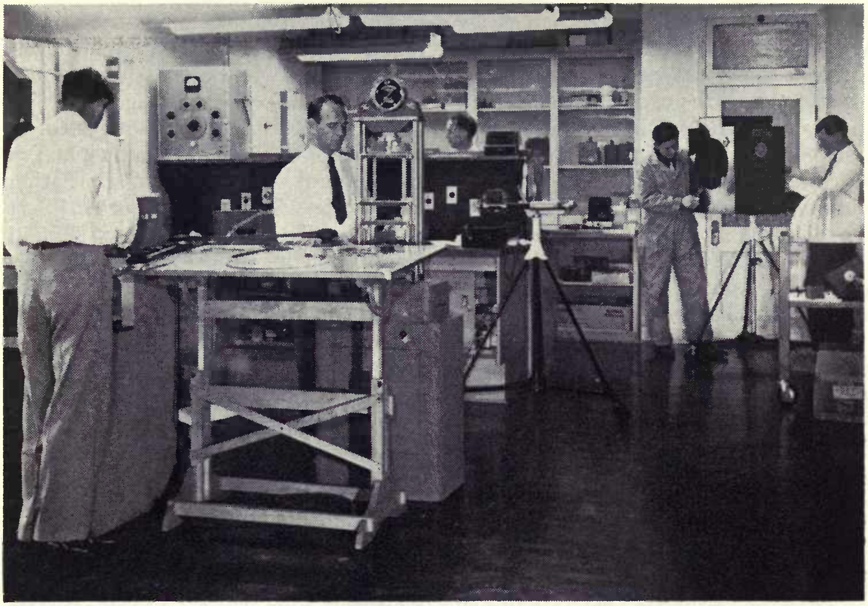


Fig. 1. Mechanical and electrical laboratory.

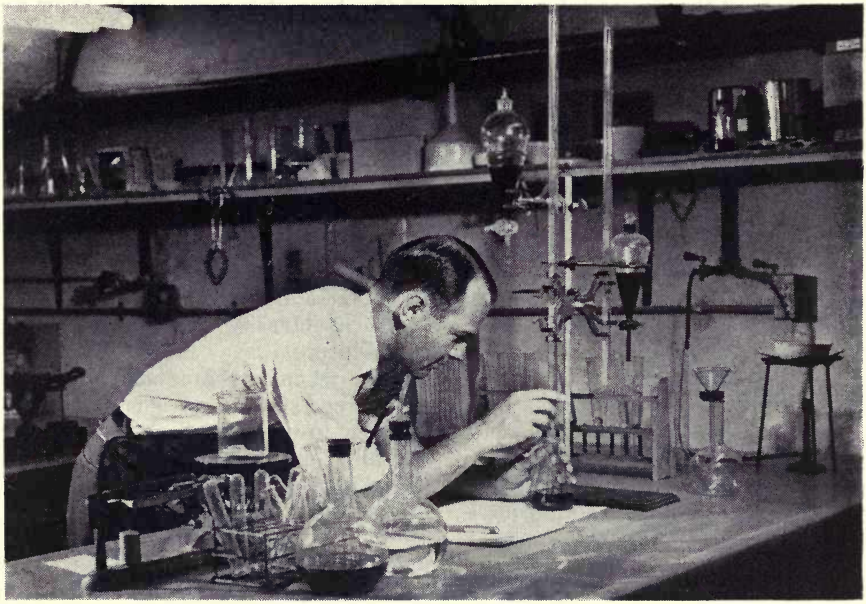


Fig. 2. Chemistry laboratory.

while Fig. 2 is one small corner of the well-equipped chemistry laboratory. Formalized laboratories of this type do not fit too well the type of work carried on by the Research Council since much of this work involves problems which can be properly studied only on a motion picture stage which, fortunately, is available through the cooperation of 20th Century-Fox on whose Hollywood Western Avenue lot is located the Research Council's office.

Although the Research Council now has its own technical staff and facilities, it needs the guidance of the many expert technicians of the industry. This is provided through a group of 14 basic committees covering every phase of the technical activity of the industry.

The Research Council is a small organization covering a broad and diverse field. Its only possible chance of working successfully under such conditions lies in the cooperation which it seeks and receives from other industries throughout the country. Since it is the purpose of the Research Council to serve the motion picture industry, it is not concerned with glory in solving problems, but only with the solution. If any other organization has a satisfactory answer, then the aims of the Research Council have been completely satisfied when that answer is made available to the industry. The cooperation of film manufacturers, equipment manufacturers, chemical companies and many others too numerous to name is gratefully acknowledged and deeply appreciated.

Set Lighting

Projects of many types and varieties are undertaken by the Research Council, either on its own or in cooperation with other companies. For example, set lighting is one of our most important projects. We will be concerned with it as long as there is a motion picture industry. Presently we are carrying on work on set lighting in all three branches of our activity, that is to say, service function, short-range design and development and long-range advanced development. Some time ago, the industry became seriously interested in the use of sealed-beam lamps and a very careful study of their application was made. This was reported in a paper before this Society at the Fall Convention in 1949.[2] Figure 3 shows an actual motion picture set at Paramount Studio which was arranged to be lighted by either sealed-beam or standard studio lamps in order that photographic tests might be made under actual operating conditions. Figure 4 shows a mercury-cadmium lamp under test. The "Man from Mars" helmet is, of course, a standard welder's helmet, equipped with special glass to permit safe viewing of the intense light produced by this mercury-cadmium lamp. Since this lamp is contained in a quartz bulb, it produces high intensities in the ultraviolet, so that artificial sunburn is difficult to avoid. In studying lamps of this type, it is necessary to know as much as possible about their color quality and variation, if any, in color quality as a function of age and various operating conditions. Such studies are made with a spectroradiometer and filtered light meters, and also photographically.

Studies of the zirconium arc, both enclosed and open-air varieties, have been carried on, although for set lighting purposes these arcs do not appear to have sufficient intensity or satisfactory color temperature.

The xenon gas arc has long been known and studied and is perhaps most familiar to us in the flashtubes so successfully used for stroboscopic high-speed photography. Not so well known is the fact that in Germany and England development work has been in progress on a high-intensity xenon arc of capacities ranging up to 1000 w. In Germany an air-cooled lamp of this type has recently emerged from the research lab-

Fig. 3. Production test setup: sealed-beam versus standard studio lamps.

Fig. 4. Mercury-cadmium lamp under test.

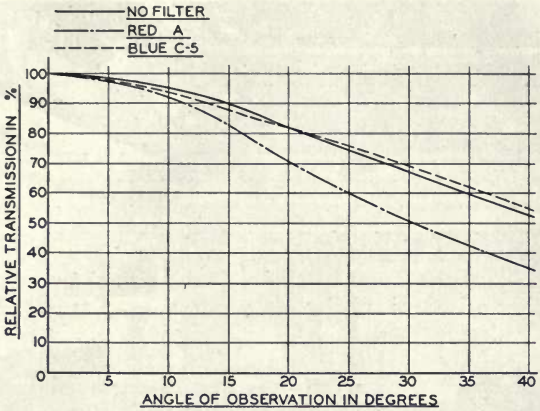


Fig. 5. Typical brightness fall-off curves—goniophotometer measurements.

oratories. It is being watched with care and samples will be obtained by the Research Council as soon as possible. This lamp has better color characteristics, having almost a continuum throughout the entire spectrum and a color temperature of the order of 6000 K (degrees Kelvin), coupled with instant starting. If it can be made commercially available, it can occupy a position of real importance in set lighting for motion pictures.

Composite Photography

Composite photography is a matter of vital importance to the motion picture industry. It permits making many shots which would otherwise be impossible, and making many more shots which would be impractical from an economic standpoint if made by any other process. There are two general types of composite photography, commonly called transparency process photography and matte photography. Both of these forms of composite photography are under study. Some of the work done on process screens was reported to the Society at the Fall Convention in 1949,[3] but much additional work in this field has been done since that time.

A goniophotometer built for our special application has been used to measure the color characteristics of transparency screens. The results of one such test are shown in Fig. 5. These tests are verified, wherever that is important, by actual photographic measurements, since it must be constantly borne in mind that the characteristics of the photographic emulsion are an inseparable part of the problem. The difference in fall-off characteristics of this particular screen sample at the different ends of the spectrum is of obvious importance for color photography, but is also important for black-and-white photography since it must effect the resultant definition in many cases.

The method of making a composite photograph which consists of photographing foreground objects while simultaneously rephotographing from a screen the desired background, can, of course,

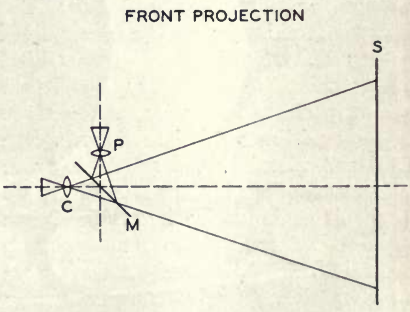


Fig. 6. Schematic drawing of front projection setup.

Fig. 7. Front projection with foreground lighting.

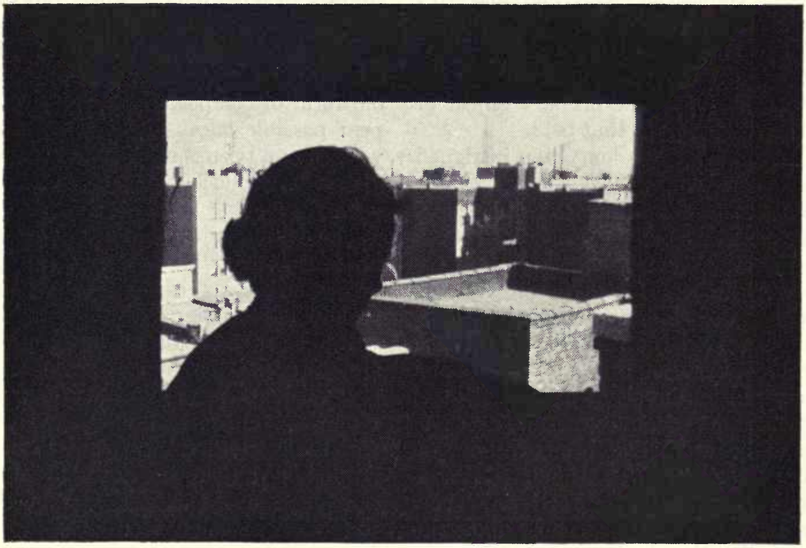


Fig. 8. Front projection without foreground lighting.

be employed with a reflection type of screen and front projection as well as with a translucent screen and rear projection. For example, in Fig. 6 is a simplified setup showing a camera, C, a projector, P, and a diaphone mirror, M. The picture from the projector is reflected by the mirror to the screen, S, and rephotographed by the camera along with the foreground object. Figure 7 is an example of this type of photography, for the young lady is seated in front of what appears to be an open window through which the city may be seen. Figure 8 shows what happens if the foreground lights are turned off so that the camera sees only the silhouette and the rephotographed view of the city. This last slide is included primarily to show that the intensity of light required from the projector is insufficient to register on the foreground object even though it is sufficient to provide a brilliant picture of the background. The differences in reflection characteristics are, of course, responsible for the operation of such an arrangement. There are many problems in connection with the successful use of front projection. The idea is not new, but its application and limitations have never before been properly defined, which is the primary object of the investigation in that field.

The industry has long been intrigued by the considerable increase in efficiency which can be obtained with a directional translucent screen as contrasted to a nondirectional screen, but in most cases the requirement for a mobile camera, coupled with manufacturing problems, has prevented the use of such screens. General awareness of the difficulties and the problems involved in a directional screen and acquaintance with much of the earlier work that has been done on this subject have also stimulated the investigation in that direction. There presently seems some promise of obtaining a directional screen which will permit of camera movement and yet offer a light gain of four or five times that presently available with the nondirectional screens.

Traveling matte composite photography presents many difficult problems. Presently, it is used in the industry only where there is no other way of making the required picture. This is true because the process is slow, expensive and it is difficult for many people to understand and appreciate the results which can be obtained. The Research Council, in undertaking an investigation of this process, expects, therefore, to work toward a system which will overcome all three of these objections. It is hoped to develop a system which will be fast and inexpensive and will permit the director, cameraman and others concerned to see the composite result at the time the foreground is being photographed. This, of course, can be true only if the background material is already available on a motion picture film. That's a rather ambitious undertaking because it involves problems of optics, photographic materials, lighting and electronics. Preliminary studies, however, lead to the belief that these highly desirable results can be achieved. The expected improvements in this rather old form of composite photography appear possible because of improvements which have been made in photographic film base, emulsions and electronic developments.

The use of projected still backgrounds has long been quite a problem, particularly where color is involved, much of the difficulty arising from the instability of the colors under the high temperature and ultraviolet light conditions which prevail. A further difficulty has been the problem of matching the foreground and background colors, since the foreground is an original and the background is a dupe. These difficulties were demonstrated with a frame of a 35-mm color print [which accompanied this paper but cannot be reproduced in

color in the JOURNAL] in which the lower left-hand quadrant is a direct photograph of a color chart, and the other three quadrants are occupied by projected reproductions of the same color chart. Two of these are still projections and the third is a motion picture projection. While none of these match the original, it is noted that the difficulty is principally in the red end of the spectrum. This is indeed fortunate since still background scenes rarely contain any significant red. Colors in such scenes are predominantly blue and green, where the comparison is not so odious. Nevertheless, this is not a satisfactory situation and it is hoped that new color films which will shortly be on the market will correct or at least improve this situation.

Transportation

Transportation between studios and location is a matter of considerable importance. When the Research Council started to analyze this problem, at the specific request of the production managers, it became apparent immediately that the problem was incapable of solution unless a reasonable amount of standardization of equipment required for a location could be achieved. Most of the equipment required for the average location is classed as "grip equipment" and an analysis covering locations made by each of the member studios of the Research Council for the last ten years developed a definite pattern which, after careful study and consultation with the grip and camera departments as well as a group of outstanding directors of cinematography, was consolidated into a standard group of equipment. This was classed as the basic list to be specified for location unless specific approval for changes was obtained from the production office.

A semitrailer was then designed about this basic list of equipment with provisions for carrying all of the grip equipment, sound equipment, camera equipment and in many cases additional equipment as required for the electrical

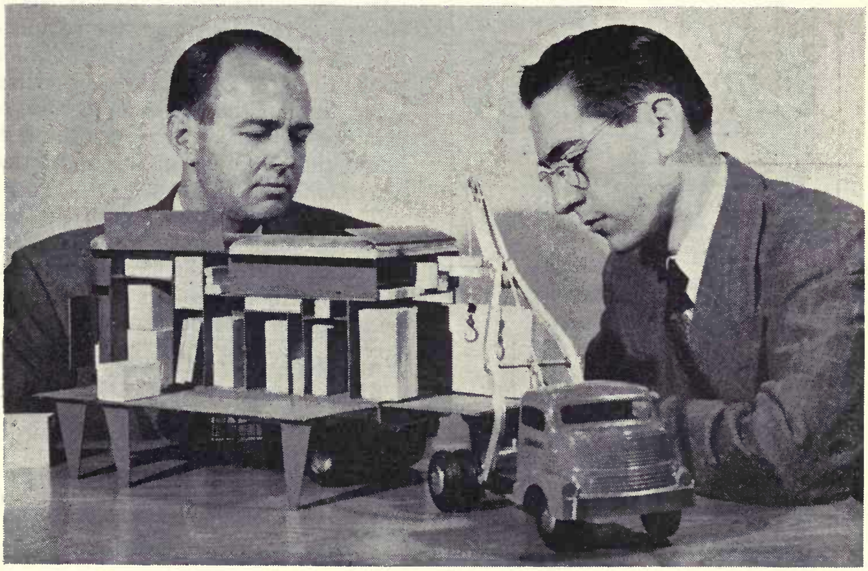


Fig. 9. First model of Research Council transportation unit.

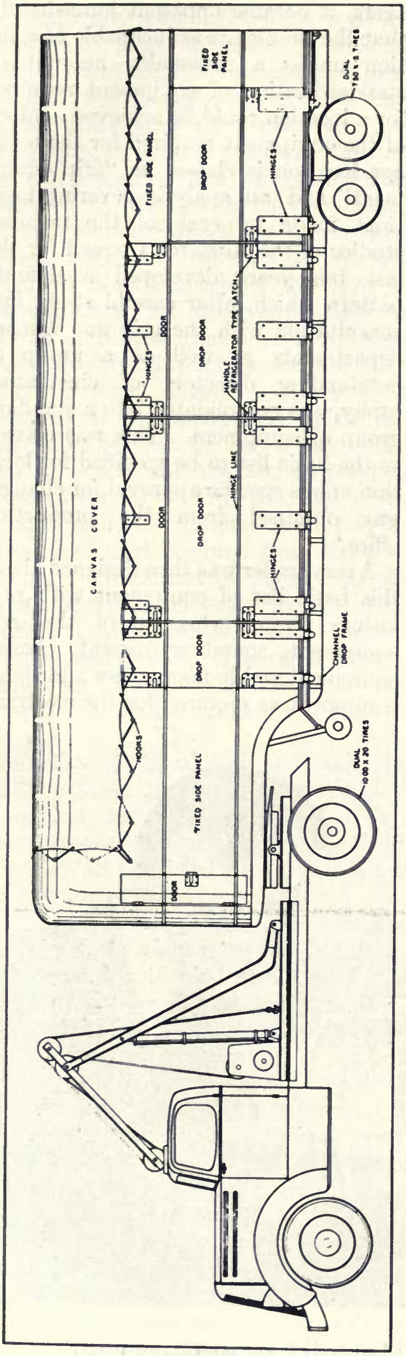


Fig. 10. Final design of "standard" location transportation unit.

department, property department or others. Figure 9 shows a model which was made up to permit graphic discussion of this problem with all of the departments involved. Subsequently, the design was changed as shown in Fig. 10. The folding crane, which is attached to the trailer, can be extended and used to load or unload any of the equipment carried by the semitrailer. It obviously can also be used in many other operations on location.

One of the important problems in designing this unit arose from the variety of state laws controlling the size of vehicles traveling over the roads. Dimensions were finally chosen to meet the requirements in most of the states of the Union. California's neighbor to the north, Oregon, offered the most difficult restriction in a height limitation of 11 ft. The standard design calls for a semitrailer having a height of 12 ft 6 in., but the front top of the semitrailer can be reduced in height to 11 ft, and if the bows are omitted from the balance of the top of the semitrailer, the complete unit can stay under the 11-ft limitation of the State of Oregon, this, of course, being accomplished at some sacrifice of carrying capacity. In most cases it is hoped that a waiver of this restriction can be obtained.

The study and tests which the Research Council has made on the very important problem of film perforations was covered in a separate paper presented at the same Convention.[4]

Wind Machines

There are many applications in the production of motion pictures for an artificial and controlled wind. These requirements vary from hurricane conditions to a gentle zephyr which blows milady's scarf. The hurricane in the past has been created by airplane motors with airplane propellers. In many cases, these motors have been

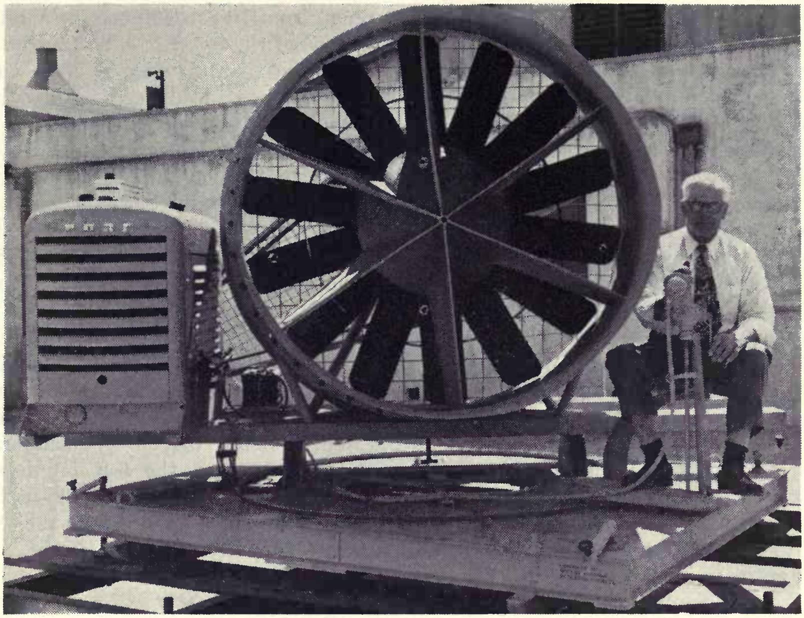


Fig. 11. 6-ft wind machine.

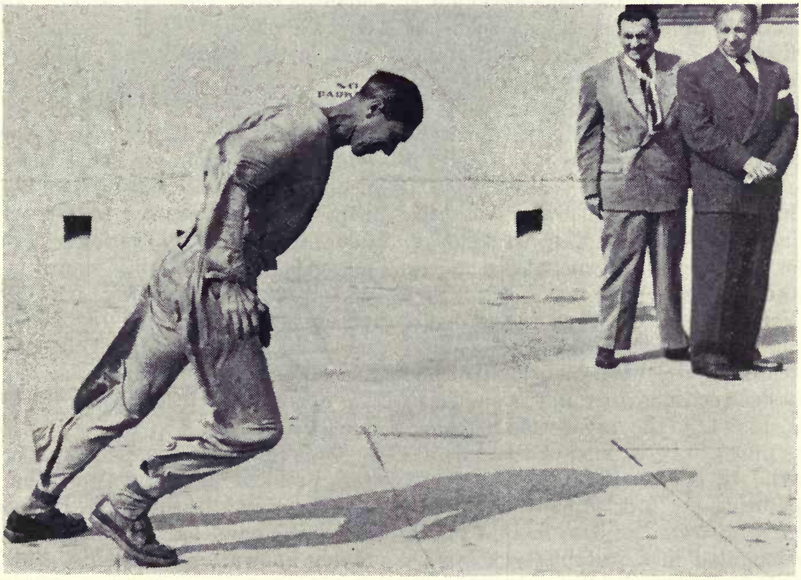


Fig. 12. Effect of windstream 20 ft from the 6-ft wind machine.

Liberty motors of the World War I vintage. Since an airplane propeller is not designed to create wind, this device, while moderately effective, was not controllable to a sufficient degree and was both noisy and expensive to operate.

Figure 11 shows a machine developed by the Research Council for the hurricane type of application. The fan blade is 6 ft in diameter and is a standard unit. The motor is a standard industrial gas engine, developing approximately 150 hp. Provision is made for mounting two of these motors, one on each side of the fan, since about 300 hp is required to drive the fan to full output. This fan may be tilted through a range of from 15° below horizontal to 20° above horizontal. The operator has control of the speed of the fan and can rotate the entire unit through 360°.

Some difficulty has been experienced in measuring the velocity of the wind created by this machine, but Fig. 12 shows graphically the intensity that is possible when the fan is driven at 200 hp. The man in the left foreground is directly in front of the wind machine at a distance of approximately 20 ft and is unable to move closer to the fan. The sharpness of the beam of wind is shown by the fact that the two men in the right foreground are almost completely out of the air stream.

Figure 13 shows the wind machine being used to blanket a set with smoke. The smoke candles can be seen at the rear of the fan.

For use inside the stage during dialog sequences, a somewhat similar wind machine, having blades 3 ft in diameter, was designed and this unit is shown in Fig. 14. Like the larger wind machine, this unit can be panned or tilted as desired. It is also designed to permit separating the fork supporting the fan unit itself from the base so that it can be mounted in a suitable socket on a parallel or on scaffolding. It is driven by a d-c motor at speeds usually in the range from 100 to 400 rpm. Wind velocities of the order of 8 to 12 mph can be created at a distance of 20 ft with a noise of about 30 db as measured by a General Radio noise level meter on the 40-db scale.

A still smaller unit has been designed, also shown in Fig. 14, again following the basic impeller principle. This unit has a blade which is 18 in. in diameter, but is somewhat similar in many other respects to the 36-in. fan. It is interesting to note that, neglecting the noise made by the driving motor, the smaller the fan the more noise it makes for a given velocity. Thus, if all three fans are driven by comparable electrical motors, the 6-ft fan is considerably quieter than the 36-in. fan, and it, in turn, is quieter than the 18-in. fan.

Motion Picture Sets

Most motion picture sets are assembled from hard flats which consist of plywood panels on light wood frames. These flats are used over and over again. Such sets are almost always covered with paper; if a wallpaper decoration is desired, the wallpaper is pasted directly to the flats; if a painted surface is desired, a blank paper is first pasted on the wall and is then covered with paint. Thus, in either case it is necessary to remove this paper to prepare the flats for reuse. In the past this has been done by various laborious methods, one of which is shown in Fig. 15. Such procedures were not only expensive in terms of time required to remove the paper, but invariably damaged the surface of the flat, requiring refinishing and necessarily reducing the life of the flat.

The Research Council approached this problem in two ways. The first was the use of the so-called "Peel-Coat" which is a paint-like material most commonly known for its use in the storage of military equipment, airplanes, ships, etc., where a cocoon of this material is

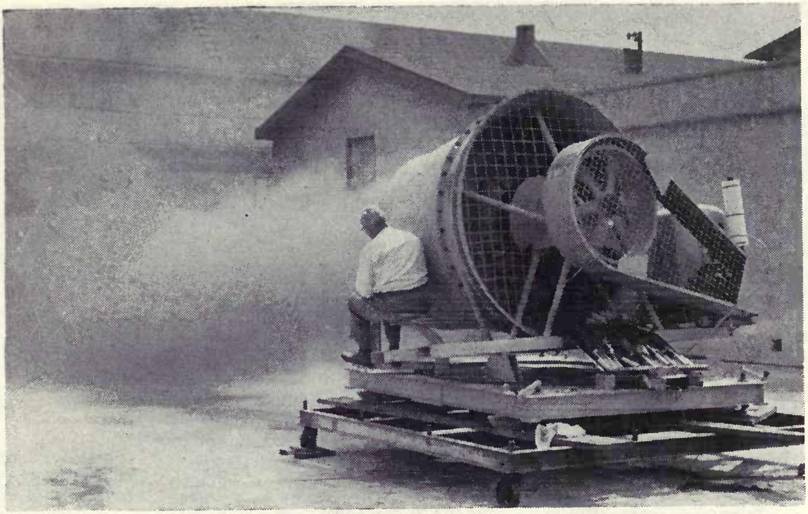


Fig. 13. Making smoke with the 6-ft wind machine.

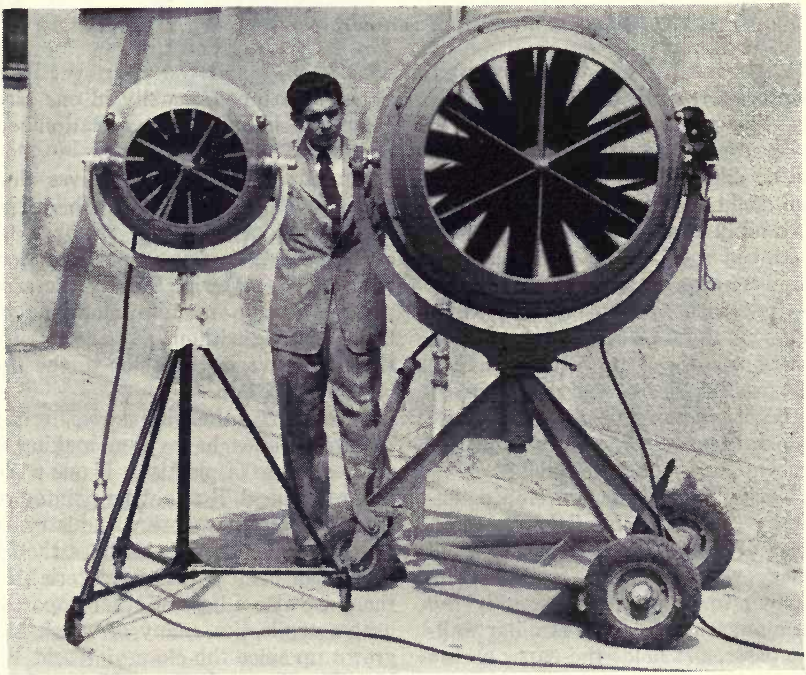


Fig. 14. 18- and 36-in. wind machines.

Fig. 15. Old style method of removing wallpaper from flats.

used to cover the device to be protected. This procedure worked with entire satisfaction, since pigments could be mixed into the Peel-Coat or a coat of paint could be applied over the Peel-Coat, or paper could be applied over the Peel-Coat, and in each case the surface could be stripped easily by the simple operation of making an incision through the Peel-Coat with a knife or other sharp instrument and then stripping the whole business off the flat. However, the process was expensive and did not meet with favor, and as a result, efforts were concentrated on a simpler solution. This came out in a material known as Peel Paste which was developed entirely by the engineers of the Research Council. It has the consistency of ordinary wallpaper paste and permits the paper to be worked in exactly the same manner as the more familiar wallpaper paste. It holds the paper on the wall satisfactorily until it is time to remove it, when again an incision is made with a knife and the entire section of paper is stripped, usually in one piece. Figure 16 shows such an operation being performed on a standing set.

Similar strippable adhesives have been developed for use with various types of floor covering; rubber tile, asphalt tile, linoleum, parquet floors and similar material. Here, the strippable adhesive permits removing the floor covering without damage to either the floor covering itself or to the floor on which it is laid.

Like most other industries, motion picture studios have been making increased usage of plastics. If one wishes to be technical, it might be pointed out that the motion picture industry depends entirely on plastics since the film base is in itself a plastic material, but there are also a host of other important usages of plastics, many of which have grown up since the close of World War II. The Research Council is constantly testing, in cooperation with the studios,

Fig. 16. New procedure for stripping wallpaper from flats.

new applications of plastics. These include such things as flexible molds for casting plaster, hardening materials to be mixed with the plaster, thermoplastic materials for set construction items such as stair handrails, plastic props, simulating metal with plastic as in the armor worn by knights, a full-scale locomotive and many others.

It is presently standard practice to move set walls from the mill to the stage and from the stage to the scene docks on wheeled platforms called set dollies. These little platforms are made up of a couple of 2 × 12's, 3 or 4 ft long, with four 2- or 3-in. free casters. They are inexpensive and their very simplicity makes them extremely versatile, but they also have some distinct shortcomings. Their stability is not good and the small casters frequently catch in holes in the ground. As a result, the Research Council has undertaken the design of an improved dolly.

All of the major studios own rather extensive, permanent outdoor sets, mostly in the form of streets of one kind or another. If any extensive shooting is to be done on these sets, it is usually necessary to cover them in with canvas so that the direction, intensity and color quality of the light will always be under the control of the cameraman. This means that each of the studios has literally acres of canvas which they call diffusing cloths. These diffusing cloths must be flameproofed to minimize the fire hazard, and this flameproofing treatment increases their weight and makes them more difficult to handle. With or without the flameproofing treatment, the life of canvas exposed to the atmosphere of Los Angeles is relatively short, perhaps two or three years.

The Research Council is, therefore, in the business of studying fabrics. First it seemed that nylon would be a natural answer since it was already flameproof and known to be considerably stronger than cotton fabrics such as canvas. Tests very quickly proved that this was not the answer, as nylon will not stand up under these atmospheric conditions as well as canvas does. Glass cloth is, of course, fireproof and stands up well under atmospheric conditions, but is easily damaged by abrasion and in many cases its tear resistance is low. There is no answer to this problem at the moment, but tests are in progress on nylon and glass cloth, each with a vinyl plastic coating.

Camera Cranes and Dollies

Some time ago the Research Council developed a camera crane which was reported to this Society in a paper presented at the 1948 Fall Convention.[5] Since that time there has been designed a dolly for this camera crane, as shown in Fig. 17. Pneumatic tires are em-

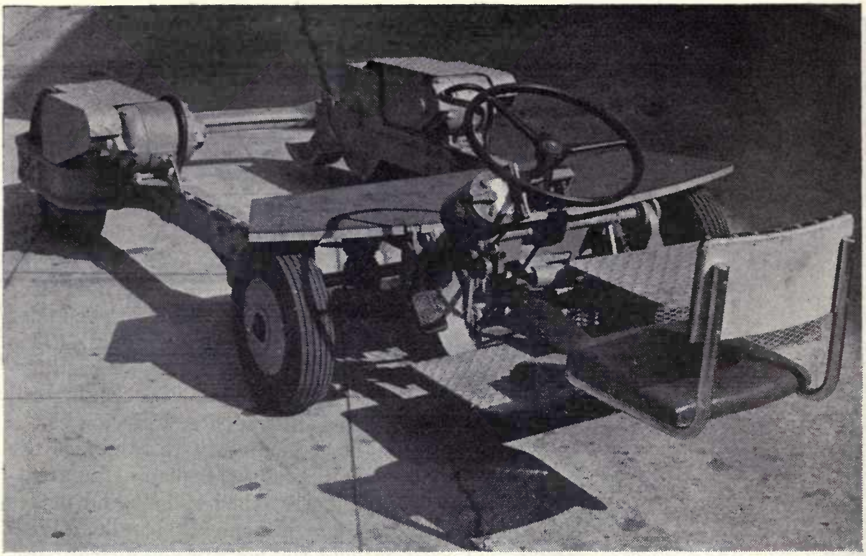


Fig. 17. Camera crane dolly.

ployed and to avoid the necessity for a differential, two series d-c motors are used to drive separately two of the wheels of the dolly. Steering, acceleration and brake have been patterned after those in an automobile in order that the operator may feel at home.

Figure 18 shows a camera crane mounted on the camera-crane dolly. The operation of mounting or removing the camera crane from this dolly can be accomplished without any special tools and without a hoist. It is but a matter of a few minutes' work.

Figure 19 illustrates a camera geared head whose design is quite different from those commonly used in the industry. It permits tilting the camera through an arc of 45° each side of the horizontal and thus has some distinct advantages over other geared heads.

Photography

Figure 20 shows a doorway at night with a light shining through the glass door panels. Actually, the door panels are made of a highly directional reflecting material and the light used was a small spotlight located on the camera. This is an example of a simple application of readily available materials which can be used to good advantage in this industry.

Although a picture is photographed on a two-dimensional medium (the film itself) and projected on another two-dimensional medium (the theater screen), the industry has always wanted a picture in three dimensions. There have been a number of papers before this Society with demonstrations of systems which permit of all three dimensions. Some of these have employed polarized light and others have obtained their separation by color, and similar procedures, but in every case they require the use of some kind of crutch by each individual in the audience, or they restrict the viewer's position and motion of his head in a most unnatural way. So far the industry has been unwilling to make any commercial use of any of these systems, except on a novelty basis.

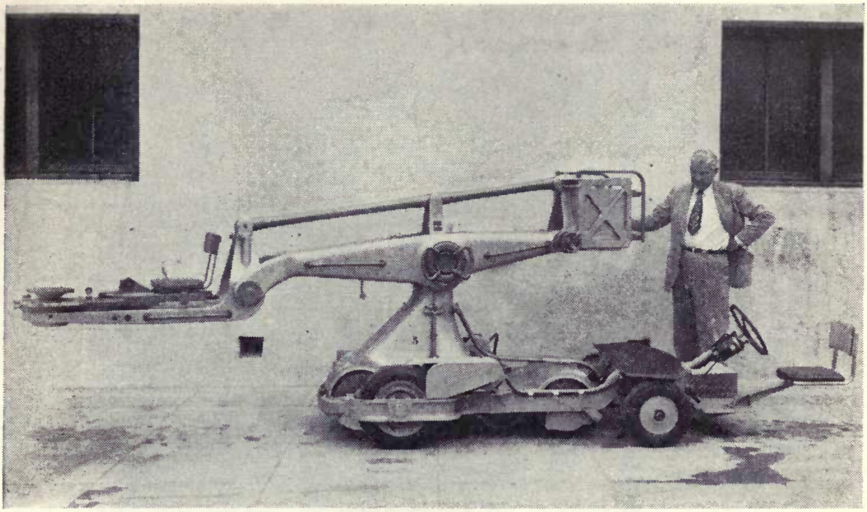


Fig. 18. Camera crane mounted on the dolly.

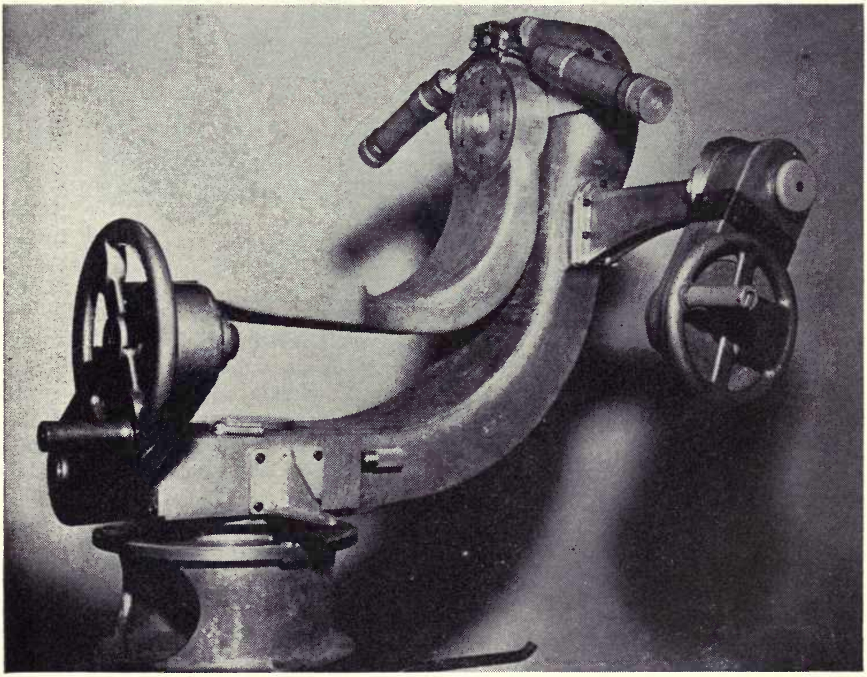


Fig. 19. Geared head.

Fig. 20. "Scotchlite" window reflector.

The Research Council is constantly receiving proposals from inventors all over the world for systems to permit three-dimensional motion pictures. So far none of these systems appears practical. Nevertheless, each one is carefully considered and investigated if that seems necessary. In order to understand better the problems of three-dimensional motion pictures, the Research Council has purchased an attachment for a 16-mm camera, as shown in Fig. 21, which permits photographing a stereo pair on the film. Figure 22 shows what this stereo pair looks like on the film. It is turned on its side to permit maximum usage of the film area and when it is projected through the same attachment used in making the picture, plus a polarizing screen, and viewed with proper analyzing glasses, a motion picture in three dimensions is obtained which is satisfactory for laboratory investigational purposes.

The Research Council activity in connection with color is largely confined to reporting to our member companies on various color systems as they are announced and studying problems of test and control for color systems which seem likely to receive commercial usage. We are consequently interested

Fig. 21. 16-Mm stereo camera.

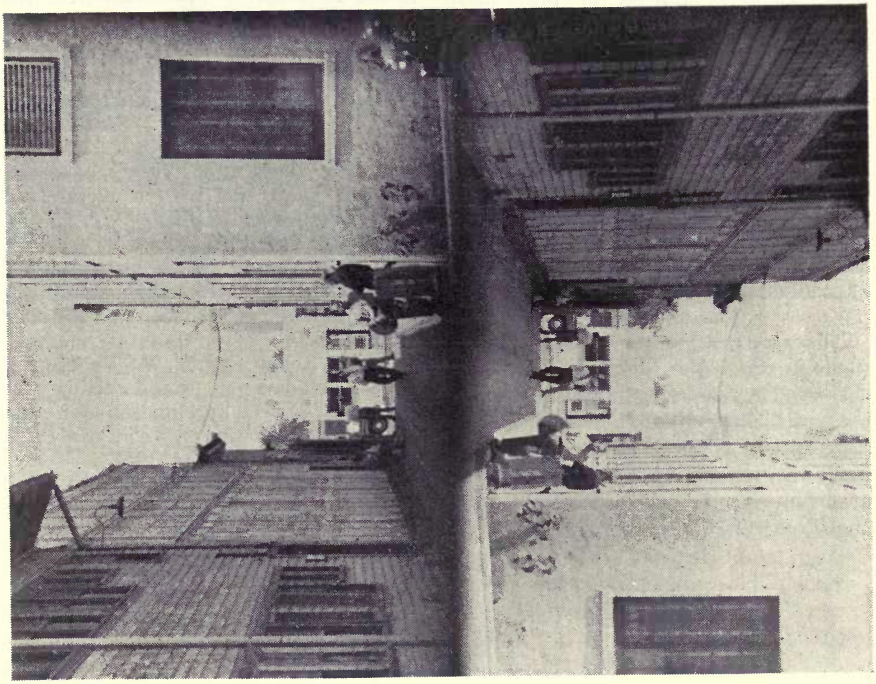


Fig. 22. Still shot through stereo attachment.

in color densitometers, color charts, printing machines and similar devices.

Magnetic Recording

In the field of magnetic recording and in the older art of photographic recording, the Research Council has not been particularly active because both the studios and their suppliers are actively at work on these problems. An analysis of the economic problems which needed consideration in connection with magnetic recording was prepared, however, because the differences in operating practices and requirements throughout the industry were creating false impressions which needed correction.

Television

Television presents another situation where the Research Council can only hope to keep abreast of that fast-changing art so that its member companies may be advised when television systems, equipment or techniques reach the place where they can be profitably applied to the production of motion pictures. In other words, the Research Council is not concerned with television as a medium of home entertainment. It is concerned with it as a medium of theater entertainment and as a means of producing motion pictures.

There are many other relatively minor items in which the Research Council is active. They include, for example, problems of flicker, elimination of static on film, special types of storage batteries, new microphone booms and refrigerated film-shipping containers. In fact, the Research Council is interested in anything which has an application as a tool in the making or exhibition of a motion picture.

There is oftentimes some confusion regarding the relationship of the Motion Picture Research Council to the Society of Motion Picture and Television Engineers. This misunderstanding usually arises from matters having to do with either standards activities or test films. The Research Council works very closely with the Society on all problems of standardization within the motion picture industry, but as a member body of the American Standards Association, the Research Council also acts directly on such problems. The Society and the Research Council work very closely together in the test-film field, each accepting orders for test films made by the other. Test films are looked upon as a service to the exhibition end of the industry which has been undertaken to insure satisfactory presentation of the studio product in the theater.

References

1. W. F. Kelley, "Motion Picture Research Council," *Jour. SMPE*, vol. 51, pp. 418–423, Oct. 1948.
2. Wayne Blackburn, "Study of sealed beam lamps for motion picture set lighting," *Jour. SMPTE*, vol. 55, pp. 101–112, July 1950.
3. Herbert Meyer, "Sensitometric aspects of background process photography," *Jour. SMPTE*, vol. 54, pp. 275–289, Mar. 1950.
4. W. F. Kelley and W. V. Wolfe, "Recent studies on standardizing the Dubray-Howell perforation for universal application," *Jour. SMPTE*, vol. 56, pp. 30–38, Jan. 1951.
5. Andre Crot, "Research Council small camera crane," *Jour. SMPE*, vol. 52, pp. 273–279, Mar. 1949.

Semiautomatic Color Analyzer

By Lloyd E. Varden

A semiautomatic color analyzer is described for rapidly determining the extent of unbalance, or deviation from "type," of a processed color negative or color positive monopack film. A standardized light source, a rotating color filter having three sectors which transmit narrow spectral bands of blue, green and red light, a multiplier-type phototube and amplifier, and a cathode-ray tube are employed. The sweep circuit of the cathode-ray tube is synchronized with the rotating filter wheel so that a horizontal straight-line image is produced when a gray or near-gray density of a "balanced" sample is in the light path. A cathode-ray tube image which deviates from a horizontal straight-line image indicates unbalance in a test sample, whereupon correction filters can be introduced in the light path by means of servomechanism devices to produce a horizontal straight-line or "balanced" condition.

IT IS WELL KNOWN that for many practical purposes a complete energy versus wavelength relationship is not always required to determine the effective spectral characteristics of a light source or of a selective absorbing material in terms of some adopted standard. Tungsten lamps, for example, can be calibrated against a black-body radiator or a suitable secondary standard, and any deviations in spectral emission from lamp to lamp can be expressed as color temperature differences or as voltage differences necessary to produce a constant color temperature. The ratio of only two values of a lamp's spectral emission, one in the blue region and one in the red region, is sufficient for such a specification.

Presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by Lloyd E. Varden, Pavelle Color Inc., 533 W. 57th St., New York 19, N.Y.

Similarly, simplified methods are utilized to express the spectral absorption characteristics of processed multilayer color films. Integral density measurements made at only three spectral positions—at wavelengths corresponding with the spectral absorption peaks of the dyes formed in the layers—are used for most laboratory control purposes. For color sensitometry, the more meaningful equivalent gray densities are preferred. These can be measured directly or can be derived from the integral densities. Such density measurements, as well as the entire subjects of color densitometry and color sensitometry, are summarized in the recent report of the Color Sensitometry Subcommittee.[1] The only point to be stressed here is that for each density specification three measurements are required. This can become a bottleneck in laboratory practice if numerous samples must be read. To use these values for setting up color correction

filter combinations is further time-consuming since the densities obtained must be correlated with the proper correction filter densities.

In the instrument to be described, a method is provided for determining very rapidly the correction filters necessary for printing a color film, assuming that all scenes will appear satisfactory when corrected to the same standard. It is recognized that any given standard, for example, gray, may not result in the most pleasing results for *all* scenes. Nevertheless, a gray balance condition as a first approximation is desirable, especially in color negative–color positive processes, since it will generally give the most acceptable over-all quality, and is the best starting point for making changes if any are indicated.

The instrument is of most value for color negative–color positive processes, because in these processes it is difficult to estimate visually what correction filters are necessary from the color negative images. Color positive images can be evaluated fairly well by visual methods, but even here large errors are possible, especially if the color of the image deviates appreciably from normal.

Description of the Instrument

The principal errors in the color balance of a reproduction arise from:

1. Light source color-quality variations,
2. Film color-balance variations, and
3. Processing variations.

The combined effects of these can be measured from control densities placed on the film for this purpose. One or more gray values can be photographed at the beginning of each scene to establish the control density at or near the middle of the density scale of the film. For convenience we can assume that the reproduction of these gray values should be gray if the light source, film color balance and processing are normal. (This may not be true, however, for intermediate reproduction steps even if gray reproduction has been accepted as normal for the final image.)

The problem, then, becomes one of determining whether or not the reproduction of gray is correct, and if not, expressing the deviation from gray in terms of correction filters required in printing to restore the gray condition.

Figure 1 is a schematic view of an instrument designed for this purpose. Its principle of operation is as follows: A standardized light source is focused upon the cathode of a multiplier phototube, the amplified output of which is connected across the vertical plates of a cathode-ray tube. In the light path immediately above the phototube is a rotating filter wheel containing three sectors. Each sector transmits but one narrow spectral band in the blue, green or red region. The filter combinations used to isolate these bands are the same as those in the original models of the Ansco Color Densitometer, giving transmission peaks at 440 mμ, 540 mμ and 660 mμ for the different filter sectors.[2] The rotation of the filter wheel is controllable from 300 to 900 rpm, but at any speed is synchronized with the horizontal sweep of the cathode-ray tube so that the first third of the tube pattern corresponds to the blue filter, the middle third to the green filter and the remaining third to the red filter.* Synchronization is accomplished by means of a small Alnico magnet on the periphery of the

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* Numerous instruments have been described for various spectral analysis purposes which employ rotating filters or other wavelength isolation means in conjunction with a photocell and cathode-ray tube. An equivalent gray color densitometer having such components was described by Senger,[3] Schneider[4] and Schneider and Berger.[5] Typical of electronic spectrographic equipment are the instruments of Feldt and Berkley,[6,7] Dieke and Crosswhite[8] and Sziklai and Schroeder.[9,10] Zworykin and Ramberg[11] give a general discussion of the subject.

wheel. This forms an electrical impulse in a coil which is amplified and used to trigger the sweep of the cathode-ray tube.

The instrument is first balanced with a "type" sample in the light path by placing neutral densities in the filter sectors until a horizontal straight-line pattern is obtained on the cathode-ray tube. With this condition established, an off-gray sample substituted for the "type" will cause amplitude changes in the cathode-ray pattern depending upon the relative change it brings about in the amount of blue, green and red light reaching the phototube. For example, a sample deficient in magenta will allow an excess of green light to pass relative to the blue and red light transmitted. Therefore, the pattern on the cathode-ray tube will no longer be a horizontal straight line, but will rise principally in the middle section corresponding to the "green" position of the rotating filter wheel. However, no part of the line image remains unaffected because the secondary absorptions of the magenta dye in the blue and red regions are also lacking.

Above the rotating filter wheel is a stack of three filter correction wheels, each having five openings. One opening in each wheel has no filter. This position, of course, is used when the instrument is balanced, or when an unknown sample is first placed in the light path. Different densities of yellow, magenta and cyan filters are in the other openings of the wheels, one color series in each wheel.* The dyes used

* Four filter densities and one blank in each of the correction filter wheels were found to be insufficient to meet all conditions in practice. Therefore, the instrument now has been revised to allow for several thousand filter combinations by adding three additional filter wheels, each having 14 apertures.

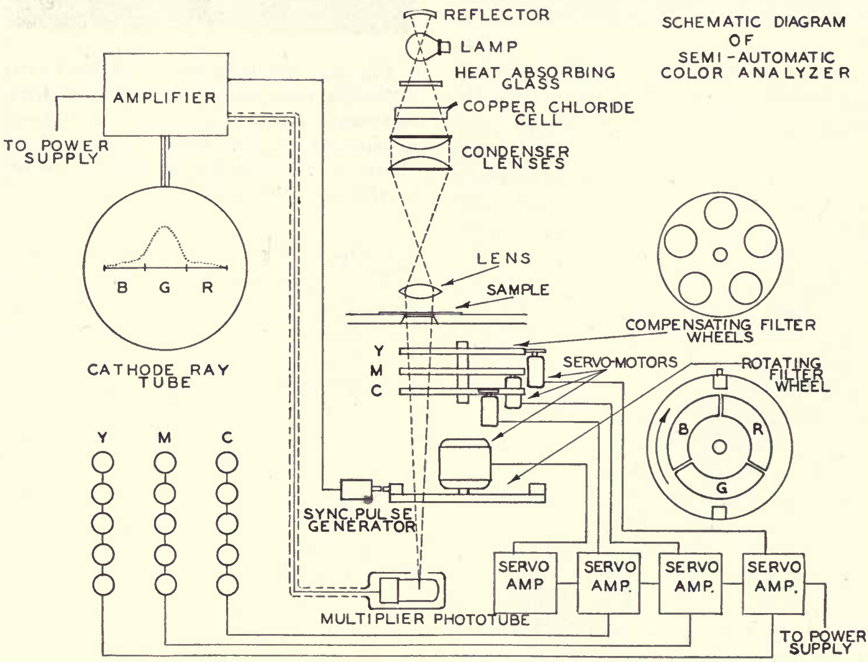

Fig. 1. Schematic view of semiautomatic color analyzer.

for these filters are the same as those which form in the layers of the color film.

The positioning of the various densities of the correction filters is accomplished by a servomechanism system, consisting of a series of pushbutton switches for each wheel, a synchro system, a servo amplifier and servomotor. When a given button is pushed down, the motor rapidly turns the wheel to place the correct filter in the light path as determined by the preset synchro system. The last button pushed down stays down so that the filters required for printing can be noted after balance has been established.

It is clear that yellow, magenta or cyan deficiencies of a sample can be ascertained by introducing the correction filters needed to restore a horizontal straight line on the cathode-ray tube. In the previous example, the magenta deficiency of the sample is compensated by use of a magenta filter of the required density. The hump in the middle of the tube pattern is flattened as increasing magenta density is introduced, and at the same time the apparent deficiencies in yellow and cyan disappear. For a color positive or color negative material the magenta density added in this case indicates directly the color and density of filter required for printing.

Figures 2a, 2b and 2c illustrate the operation of the instrument. In Fig. 2a is shown the straight-line, balanced condition in which the "type" sample is in the light path and all three of the correction filter wheels are in the no-filter position. When the magenta-deficient sample is placed in the light path in place of the "type" sample, the cathode-ray tube pattern changes as shown in Fig. 2b. By introducing the proper density magenta filter, the straight-line condition is restored, as shown in Fig. 2c. The fourth button in the middle row of buttons was pushed down to re-establish the balance of the instrument for this particular sample.

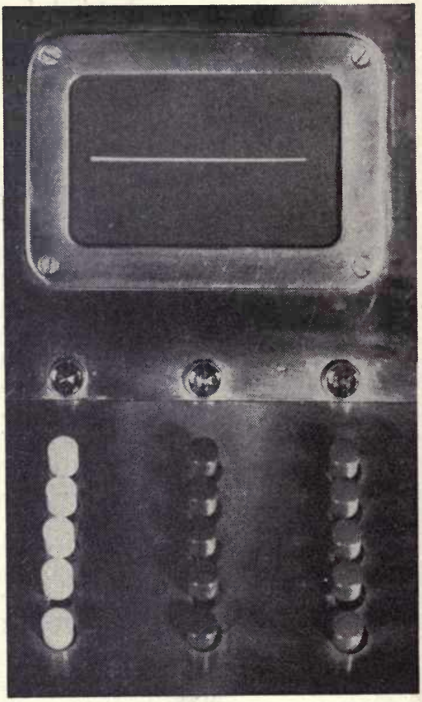

Fig. 2a. Photograph of cathode-ray tube pattern showing straight-line, balanced condition when a "type" sample is in the light path and all three correction filter wheels are set in the no-filter position.

The control density of the sample to be analyzed is not critical, but it should fall along the straight-line portion of the D-$\log_{10}E$ curves where it can be assumed that the curves for the blue, green and red densities are parallel. If the curves are not parallel the instrument will merely indicate the filters necessary to pull the curves together at one cross-over point. Parallelism of the curves can be ascertained with the instrument by use of a graded density sample. When such a sample is balanced for one density and then moved slowly from this density level to another, the cathode-ray pattern remains

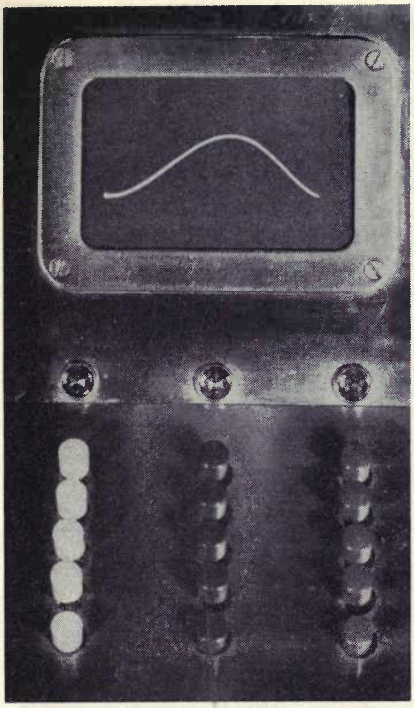

Fig. 2b. Photograph of cathode-ray tube pattern for a magenta-deficient sample. The central hump indicates the excessive green light transmitted by the sample.

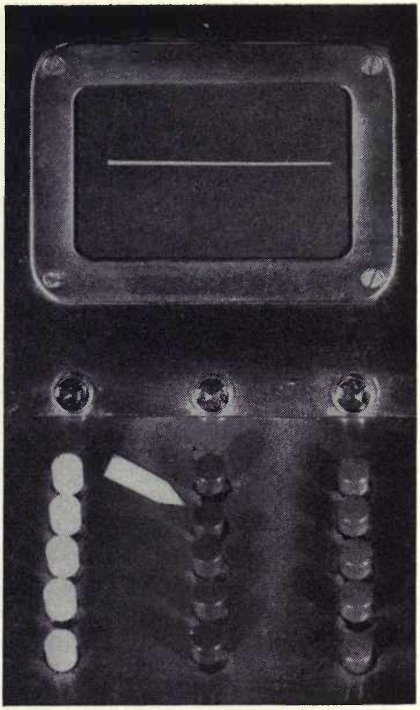

Fig. 2c. Photograph of cathode-ray tube pattern for same sample as used for Fig. 2b, except a magenta correction filter has been introduced into the light path by pressing button indicated by arrow.

a straight-line if the curves are parallel. If the curves are not parallel, each change of density in the sample will require different balancing filters.

Figure 3 shows an over-all view of the instrument. The pushbuttons for positioning the correction filters, the cathode-ray tube screen and the aperture for placing the sample are in line, one above the other, with the cathode-ray tube placed at an angle for convenience in observing the pattern. At the sample position a sliding tube is provided to uncover the aperture for inserting the sample in the light path. When this tube is in the "up" position the aperture is illuminated from beneath so that the film density to be evaluated can be situated properly. The tube is then lowered over the sample to cut out extraneous light and to secure the film.

Figure 4 shows a close-up view of the control panel. The dials in the back are for presetting the synchro system so that the openings of the filter correction wheels fall in the light path. A stand-by switch is provided so that the power supply can remain on when the instrument is not in use. A speed adjustment for the rotating filter wheel is essential to obtain a smooth, steady trace on the cathode-ray screen. The usual cathode-ray tube controls are

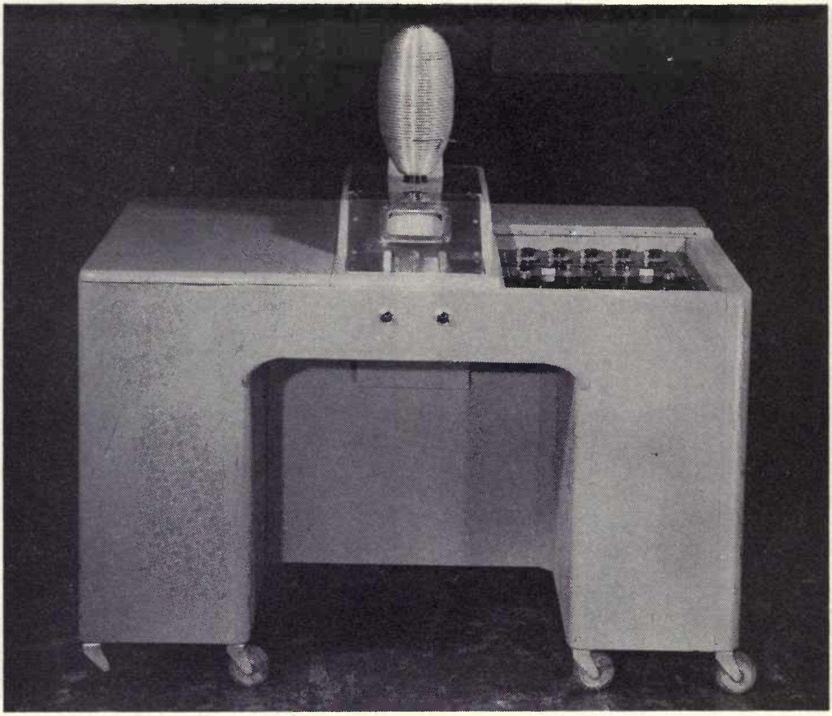

Fig. 3. Over-all view of color analyzer.

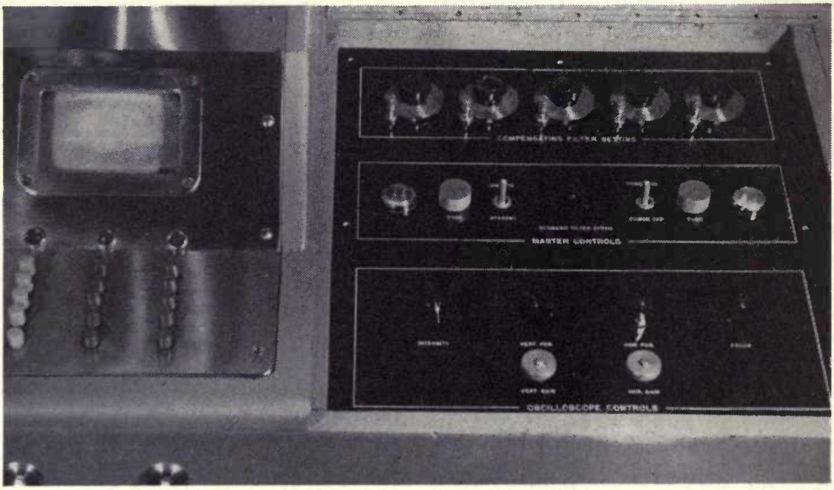

Fig. 4. Close-up view of control panel.

Fig. 5. Internal view of rotating filter mechanism, correction filter wheels, photomultiplier tube and servo amplifier units.

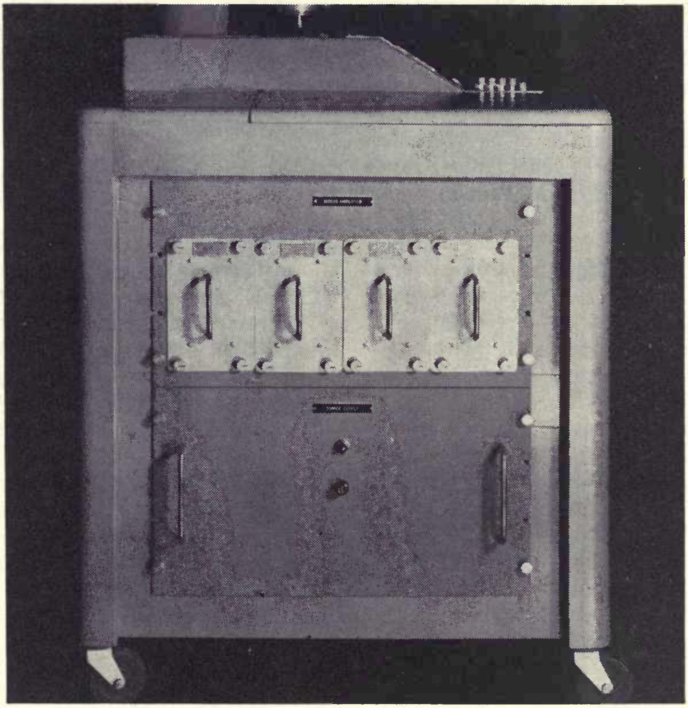

Fig. 6. View of one side of the color analyzer cabinet showing the readily removable electronic units.

also provided for positioning the trace in the center of the screen, for increasing or decreasing the brightness of the image, for focusing and for controlling the amplitude response. It is seldom necessary to use any of these controls once the instrument has been adjusted.

Figure 5 shows the internal mechanism of the filter correction wheels, the rotating filter wheel, the servomotors, etc. Also shown in Fig. 5 is an inside view of two of the servo amplifier units. These are standard units manufactured by Servomechanisms, Inc., Mineola, L.I., and are readily removable for inspection.

One side of the instrument is shown in Fig. 6 to illustrate how the electronic components are fitted into the cabinet for convenient servicing.

Acknowledgments: The following people have given valuable assistance in the final design, construction or testing of the instrument: Dr. Herman Duerr, Monroe H. Sweet and John Forrest of Ansco; William Shannon and Ralph Redemske of Servomechanisms, Inc.; Leo Pavelle, Peter Krause and Rudy Seefried of Pavelle Color Inc.

References

1. "Principles of color sensitometry — a report of the Color Sensitometry Subcommittee," *Jour. SMPTE*, vol. 54, pp. 653–724, June 1950.
2. M. H. Sweet, "An improved photomultiplier tube color densitometer," *Jour. SMPTE*, vol. 54, pp. 35–62, Jan. 1950.
3. N. Senger, "Progress in the field of the Agfacolor process," *Film und Farbe* (Dresden, 1942), pp. 11–14, Max Hesses, Berlin, 1943.
4. W. Schneider, "The Agfacolor process," *FIAT* Final Report No. 976, n.d.
5. W. Schneider and H. Berger, "On the sensitometry of the Agfacolor process," *Zeits. f. wiss. Photographie, Photophysik und Photochemie*, vol. 42, pp. 43–52, 1943.
6. R. Feldt and C. Berkley, "The cathode-ray spectrograph," *Proc. Nat. Electronics Conf.*, pp. 198–211, Oct. 1946.
7. R. Feldt and C. Berkley, U.S. Pat. 2,444,560.
8. G. H. Dieke and H. M. Crosswhite, "Spectrochemical analysis with the oscillograph," *J. Opt. Soc. Amer.*, vol. 36, pp. 192–195, 1946.
9. G. C. Sziklai and A. C. Schroeder, "Electronic spectroscopy," *J. Appl. Phys.*, vol. 17, pp. 763–767, 1946.
10. G. C. Szirlai and A. C. Schroeder, U.S. Pat. 2,519,154.
11. V. K. Zworykin and E. G. Ramberg, *Photoelectricity and Its Application*, Wiley & Sons, New York, 1949.

Motion Picture Studio Lighting Committee Report

By M. A. Hankins, Committee Chairman

During the past several years the Motion Picture Studio Lighting Committee reports and papers have described studio lighting equipment, set power distribution and power supply.[1-6] Some mention has been made of set lighting levels and lamp location but the variables are so great it was found exceedingly difficult to provide the information within the scope of a paper or report.

Because of numerous requests for at least a general picture of set lighting levels and equipment placement, this report will describe and illustrate representative sets which were lighted for three-color photography and come within what may be termed as "high-key" lighting.

In set lighting for motion pictures the cinematographer thinks more in terms of obtaining an emotional effect that will carry the mood of the picture to the audience than upon correct exposure alone. If he must make a choice between working within the normal latitude of the film or obtaining the best dramatic effect, he will usually choose the latter course. Whether or not his result is satisfactory is a measure of his combination of artistic and engineering ability.

From an engineering viewpoint he may find it desirable to establish his key-light in the middle range of the latitude of the film and to restrict highlight and shadow areas to a ratio that will assure correct exposure. From an artistic viewpoint, however, he may not be able to obtain the dramatic effect for which he is striving and he will experiment outside of engineering limits for the best combination of exposure and dramatic effect.

The key-light levels on the color sets described vary from 500 to 600 ft-c. While there may be instances of sets which are photographed at higher levels than those indicated, for the most part the trend would be downward, even toward key-light levels as low as 50 ft-c on some gangster, or mystery type, black-and-white pictures.

A study of the following data will cause some to wonder why a set is rigged with more lamps than the total operating load indicates as having been used. The question is answered by the fact that when the cinematographer starts shooting he must have lamps in place for long shots, medium shots, dolly shots, and close-ups to avoid the necessity of the loss of expensive shooting time in moving lamps.

Quite often the cinematographer sees a given set for the first time shortly before he starts to photograph the picture. He has had little to do with the shooting arrangement, color balance

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Presented on October 19, 1950, at the Society's Convention at Lake Placid, N.Y.

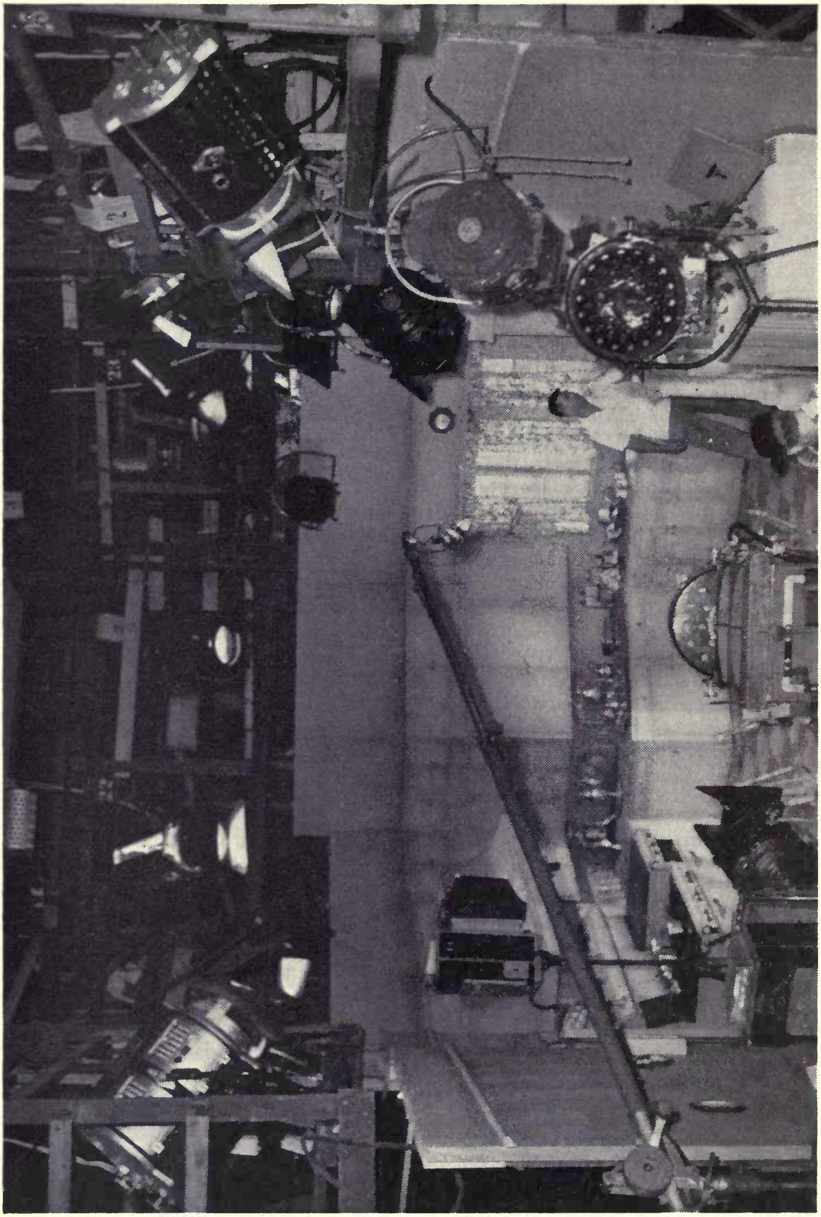


Fig. 1. Lighting arrangement of butler's pantry scene in *Lullaby of Broadway*. Courtesy of Electrical Dept., Warner Bros. Pictures, Inc.

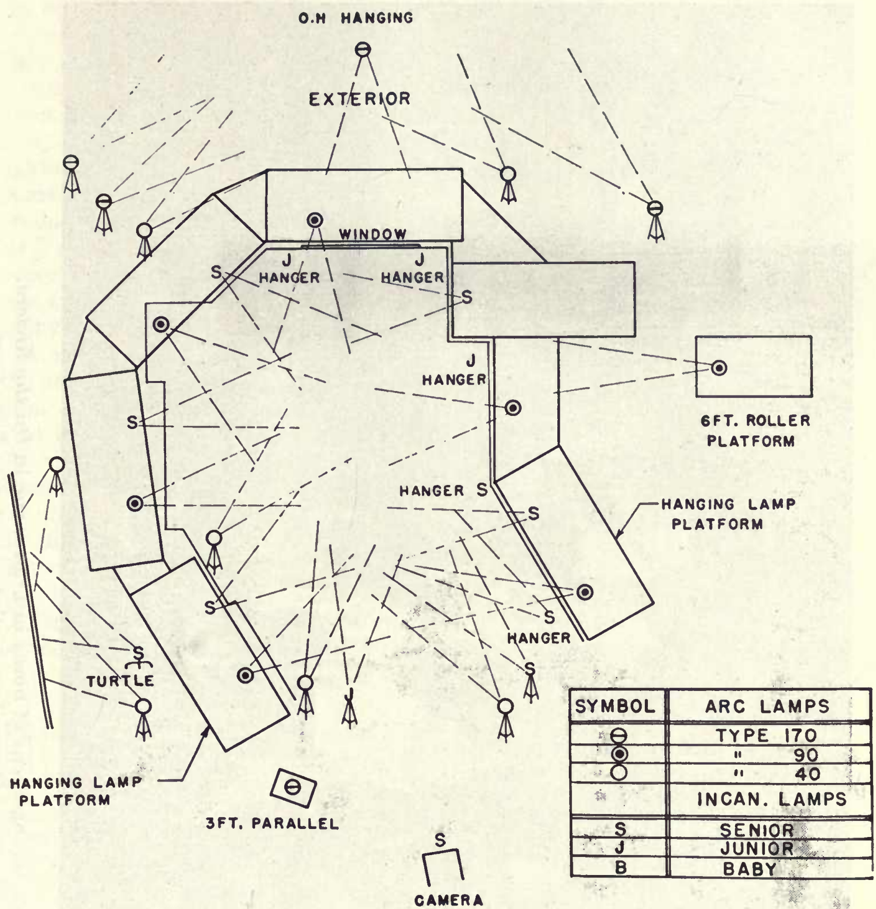


Fig. 2. Gaffer's layout of butler's pantry scene in *Lullaby of Broadway*. Courtesy of Electrical Dept., Warner Bros. Pictures, Inc.

or general preplanning, yet he must be in a position to establish and maintain key-light levels on characters who are moving about, and often with the camera in movement on a dolly as well. Furthermore, even after shooting has started, he is often called upon to rearrange his lighting for a different camera angle than was originally planned.

It would seem, if the latitude of the particular color process is to be sacrificed for dramatic effect, there would be little hope of expecting the optimum in color quality. In actual practice the reverse is true because color quality has been steadily improving in the face of fewer restrictions placed upon the cinematographer and of lower light levels being used. It is merely a case where the end result is *dramatic effect* and engineering ability is being applied to make the process meet the needs of the end result rather than the apparent exposure requirements of the film alone.

It is a virtual impossibility to establish hard and fast rules and regulations for

Fig. 3a. Lighting arrangement of home interior scene in *On the Riviera.* Courtesy of Electrical Dept., Twentieth Century-Fox Film Corp.

the lighting of a given motion picture set since each cinematographer will light a set to satisfy his individual artistic interpretation of the dramatic effect he is striving to produce. However, in order to indicate general set-lighting requirements, a survey was made of three motion picture sets in production: a small set, one of medium size and a large one. Information concerning how these representative sets were lighted for three-color photography is contained in Table I.

A study of Table I shows that while the area of the set in *Lullaby of Broadway*, Figs. 1 and 2, was only half of that in *Home on the Riviera*, Figs. 3a, 3b and 4, the total peak load was almost the same. This may be accounted for by the actual area being illuminated on the set, by the type of lamps needed for the particular effect and by the mood of the effect itself. In Figs. 1 and 2 a higher key-light level is maintained than on the scene shown in Figs. 3a, 3b and 4. However, less light is needed on the walls to bring them into proper perspective with the balance of the scene. Also, in Figs. 1 and 2 the shadow areas are illuminated, whereas in Figs. 3a, 3b and 4 they are allowed to go black.

The *Samson and Delilah* set, illustrated in Figs. 5 and 6, shows the lighting equipment used on large areas where daylight intensity is indicated. It is interesting to note that the high light-to-shadow ratio was maintained within narrower limits than on the other sets illustrated.

References

1. R. G. Linderman, C. W. Handley and A. Rodgers, "Illumination in motion picture production," *Jour. SMPE*, vol. 40, pp. 333–367, June 1943.
2. "Report of the Studio Lighting Committee," *Jour. SMPE*, vol. 34, pp. 94–97, Jan. 1940.

(*concluded on p. 211*)

Table I. Data on the Lighting for Three-Color Photography of Representative Motion Picture Sets of Small, Medium and Large Size.

		Lullaby of Broadway	*On the Riviera*	*Samson and Delilah*
Scene		Butler's Pantry	Home Interior	Temple of Dagon
Width of set, ft		16	25	75
Length of set, ft		28	40	265
Area of set, sq ft		448	1000	19,875
Height of lamp parallels, ft		14	13	25, 30 & 34
Color of walls		light blue – green	tan	grayish yellow
Key-light level, ft-c		600	500	550
Average light level on walls, ft-c		200	300	500
Min. light level in shadow area, ft-c		50	approx. zero	100
Max. highlight level, ft-c		600	500	550
Camera lens diaphragm opening		$f/2.2$	$f/2.2$	$f/1.9$
Type and number of arc lamps available on set	Type 450			30
	Type 170	6	7	232
	Type 90	11	12	42
	Type 40	15	14	40
Type and number of incandescent lamps available on set	Senior	16	40	14
	Junior	13	21	
	Baby	15	12	
	Sky Pan			24
Total paper load, amp		3985	5550	57,090*
Peak load used, amp		2450	2860	48,000
Photographs of set		Fig. 1	Figs. 3a and 3b	Fig. 5
Gaffer's layout sketch		Fig. 2	Fig. 4	Fig. 6

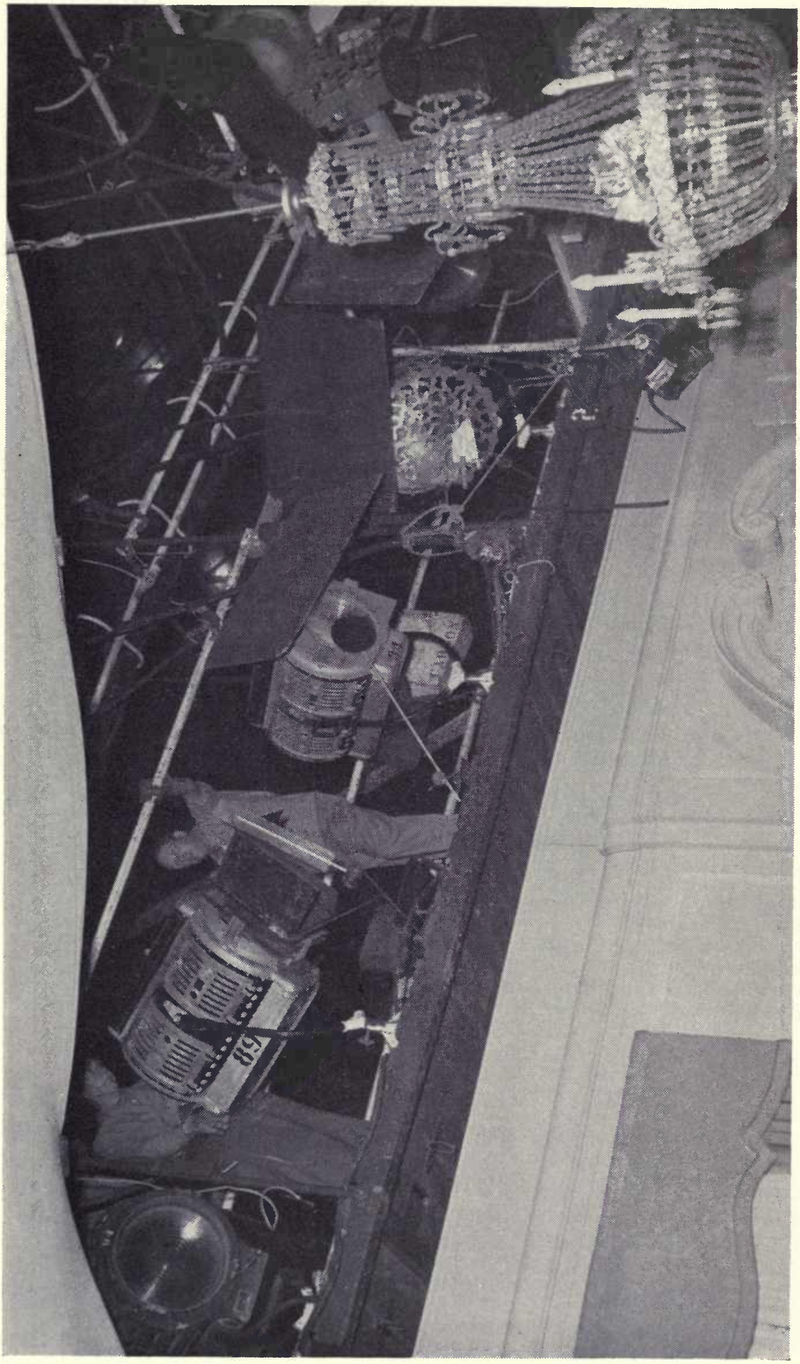
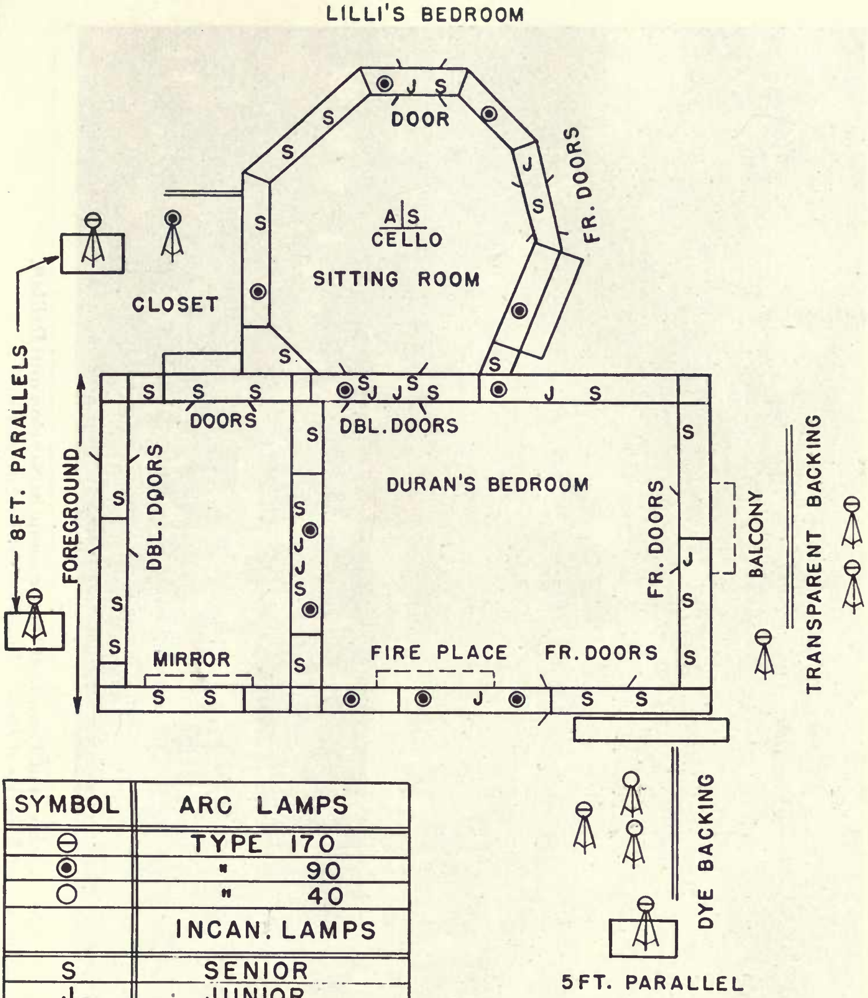


Fig. 3b. Positions of lamps and control devices for home interior scene in *On the Riviera.* Courtesy of Electrical Dept., Twentieth Century-Fox Film Corp.



SYMBOL	ARC LAMPS
⊖	TYPE 170
⊙	" 90
○	" 40
	INCAN. LAMPS
S	SENIOR
J	JUNIOR
B	BABY

Fig. 4. Gaffer's layout of home interior scene in *On the Riviera*. Courtesy of Electrical Dept., Twentieth Century-Fox Film Corp.

3. ———, *Jour. SMPE*, vol. 35, pp. 607–609, Dec. 1940.
4. ———, *Jour. SMPE*, vol. 47, pp. 113–118, Aug. 1946.
5. ———, *Jour. SMPE*, vol. 49, pp. 279–288, Sept. 1947.
6. ———, *Jour. SMPE*, vol. 51, pp 656–666, Dec. 1948.

Committee Members

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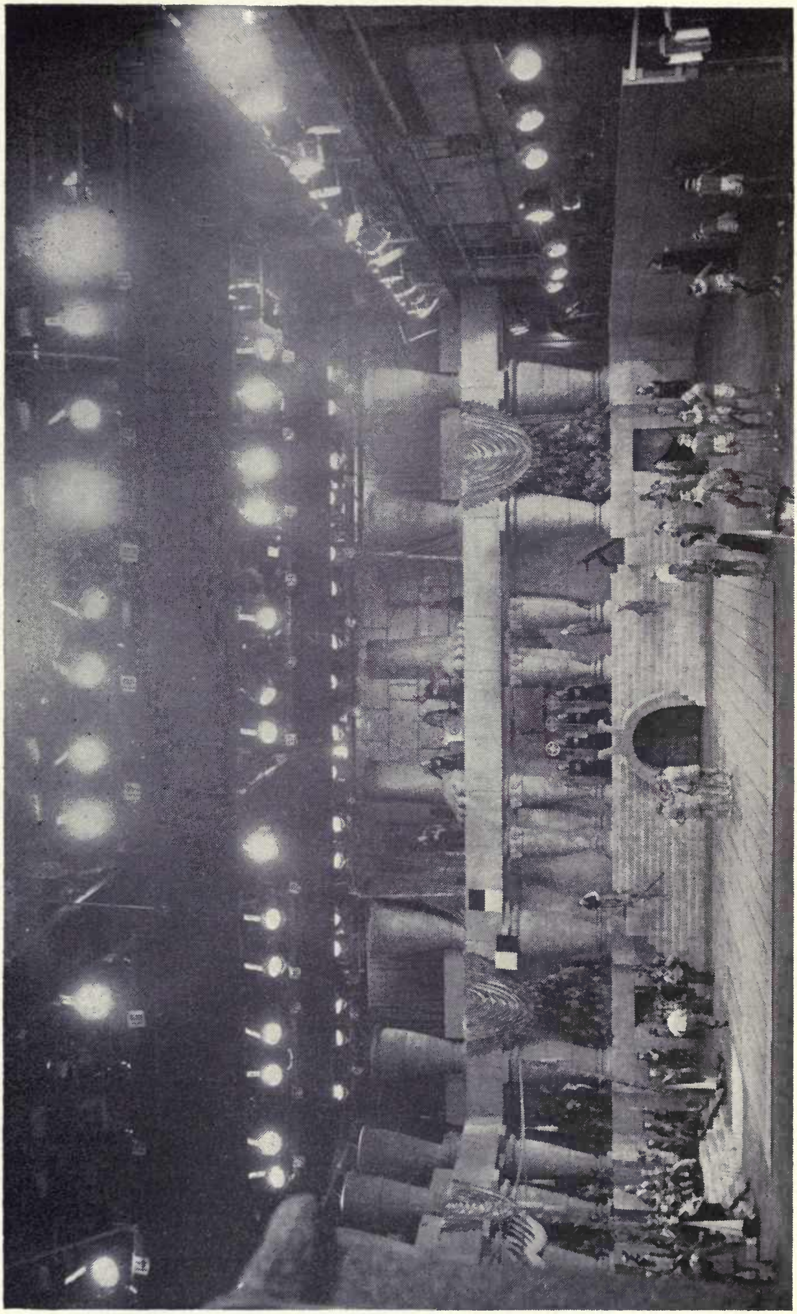

Fig. 5. Lighting arrangement of Temple of Dagon scene in *Samson and Delilah*. Courtesy of Electrical Dept., Paramount Pictures, Inc.

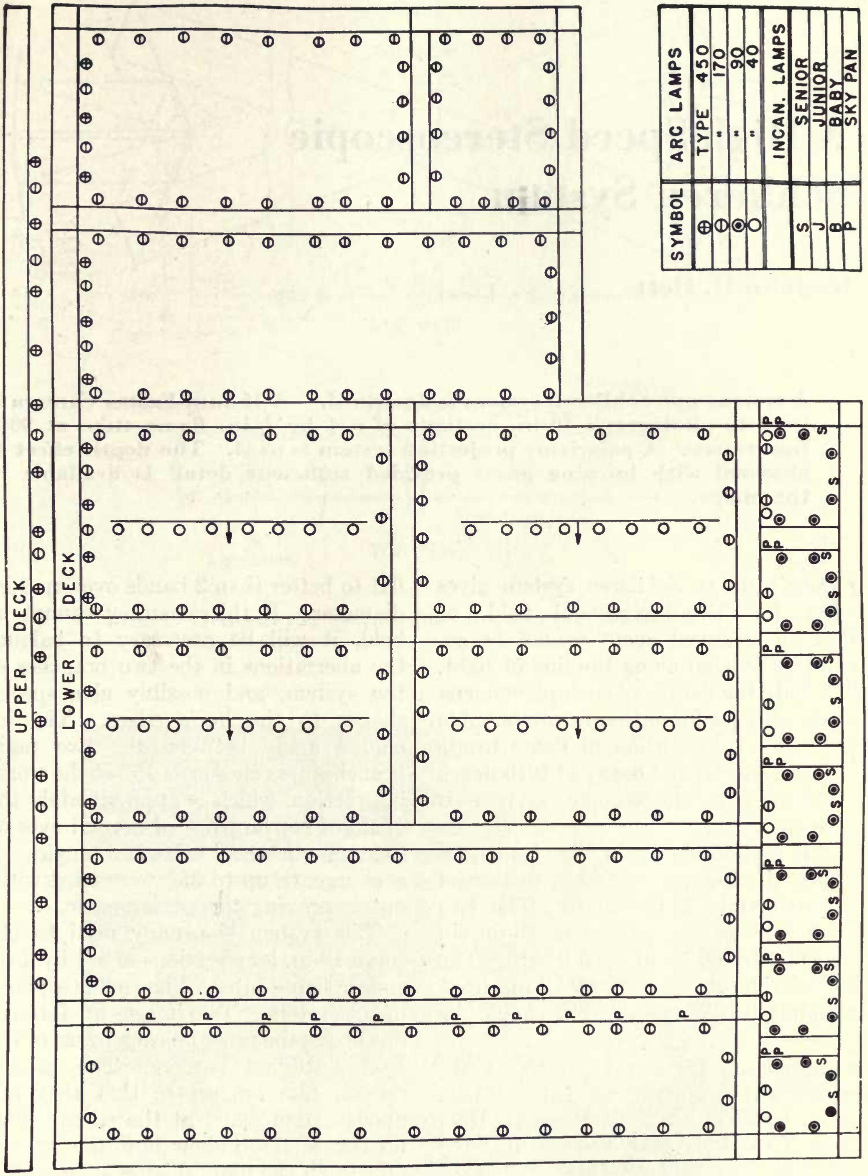

Fig. 6. Gaffer's layout of Temple of Dagon scene in *Samson and Delilah*. Courtesy of Electrical Dept., Paramount Pictures, Inc.

A High-Speed Stereoscopic Schlieren System

By John H. Hett

A stereoscope Schlieren system is described. A 16-mm Fastax Camera is used to photograph 10-in. sections of a 4 by 4 in. flame tube at 9000 frames/sec. A polarizing projection system is used. The depth effect is observed with burning gases provided sufficient detail is available in the image.

The normal Schlieren system gives a flat two-dimensional field, so that an observed event cannot be accurately located along the line of sight. To study the details of such phenomena as burning jet formation in combustible gases, the acceleration of flame fronts and the growth and decay of turbulence in flames, a stereoscopic system is indicated.

The system shown in Fig. 1 was designed to observe a working section of approximately 5 by 10 in. The two large mirrors are parabolae 16 in. in diameter by 60 in. in focal length. The flat mirrors, *A*, are 6 in. by 10 in., front aluminized. These mirrors should be flat to better than 2 bands over an 8-in. diameter. If this accuracy cannot be held, it will be necessary to balance the aberrations in the two branches of the system, and possibly give special shapes to the knife edges. The included angle between the two main branches was chosen as 15° at the working section, which is approximately the angle of convergence of normal eyes at reading distance. Higher angles of convergence up to 35° were tried without improving the performance.

This system is usually used to observe 10-in. long sections of a 4 by 4 in. square flame tube. Figure 2 is a photo of the system. Two images are formed, one above the other on each frame of the Fastax 16-mm camera. The images on the film are set so that they are about 1 mm apart at the edges. Figures 3a and 3b show how the images appear on the film. Figure 4 shows the test hexagon.

The light source used is a 100-w zirconium lamp with a horizontal cylindrical condenser. The two knife edges are also horizontal, that is, in the plane of the axis of the flame tube; each knife

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Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y., by John H. Hett, Research Div., New York University College of Engineering, University Heights, New York 53, N.Y. The work described in this paper was done with the support of the Office of Naval Research, Dept. of the Navy, and the Office of Air Research, Dept. of the Air Force, under Contract N6ori-11, Task Order 2, as part of Project Squid.

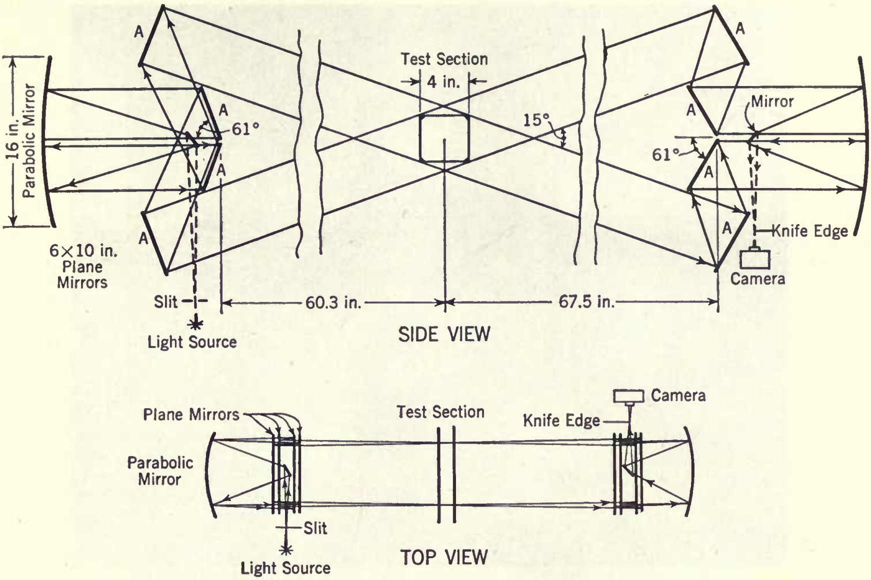


Fig. 1. General ray system for stereoscopic Schlieren.

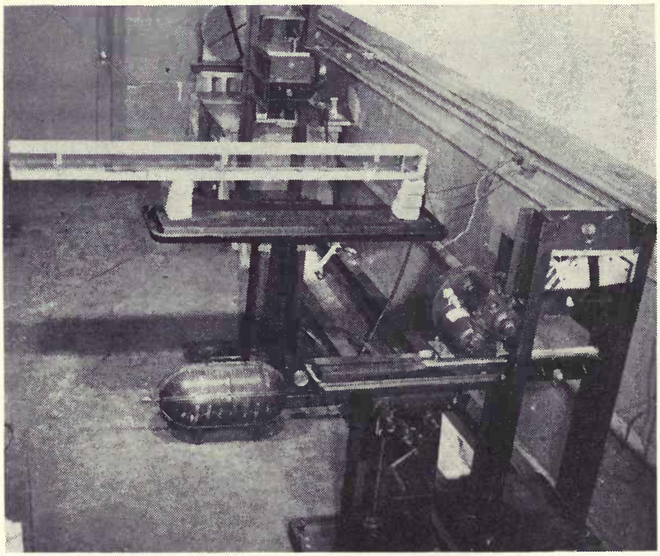


Fig. 2. Photo of the system from camera end, showing 6-ft flame tube in position.

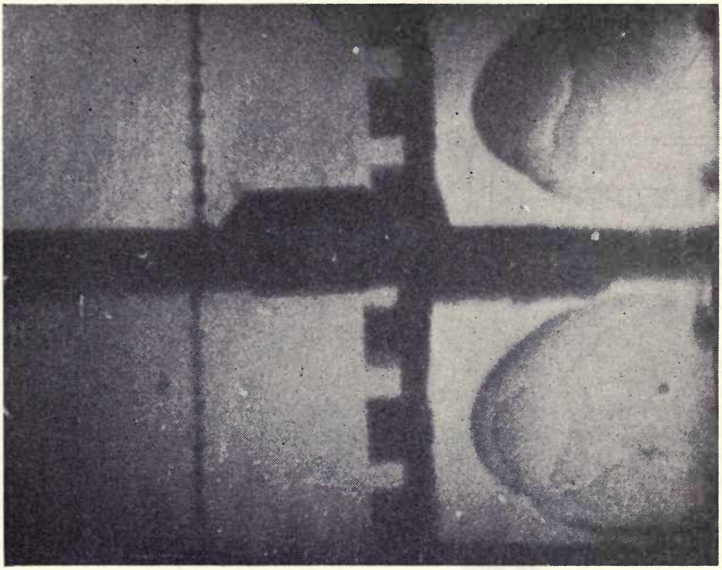


Fig. 3a. Stereo pictures of flame front about 25 msec after spark ignition of stoichiometric mixture of propane–air in flame tube.
The heavy black transverse image is a 3-hole grid placed across the tube.

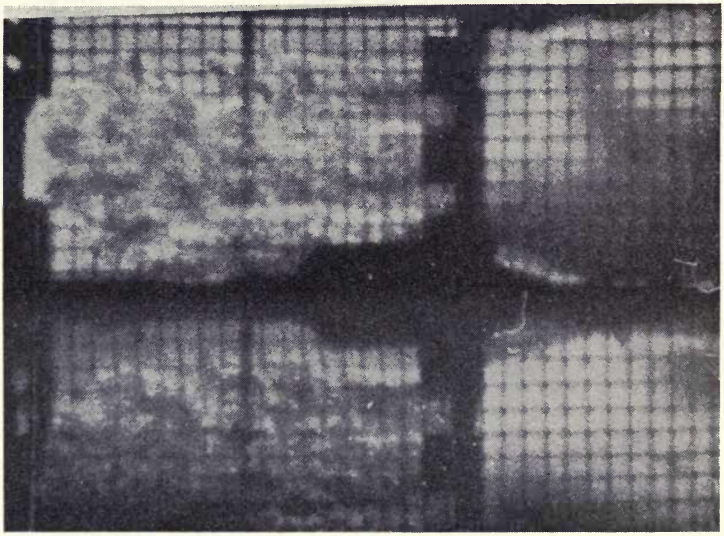


Fig. 3b. The turbulent flame after passing through the grid. The wire mesh was added as a reference frame behind the back surface of the tube.

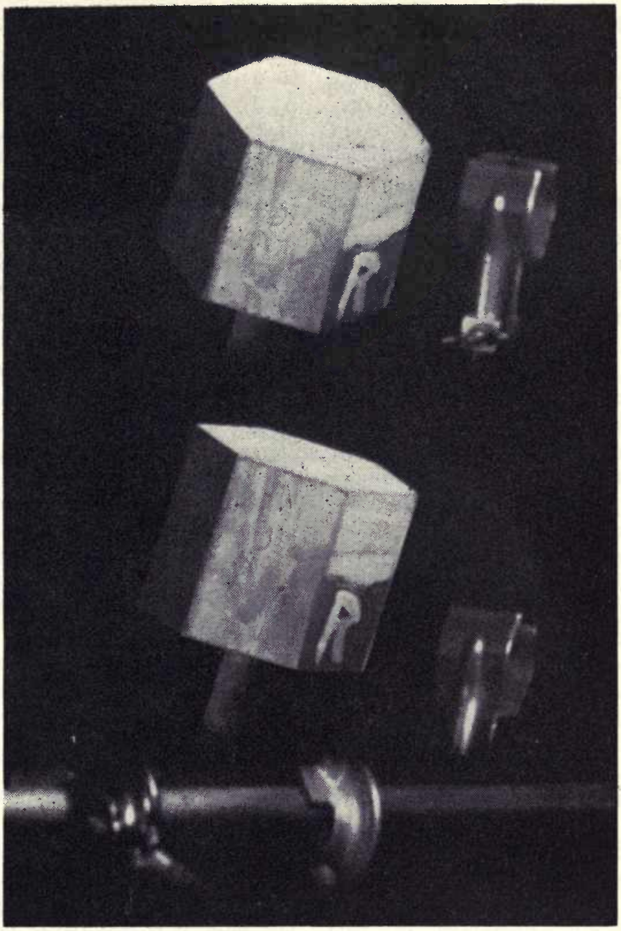


Fig. 4. The two images of the test hexagon. These can be rotated at high speed.

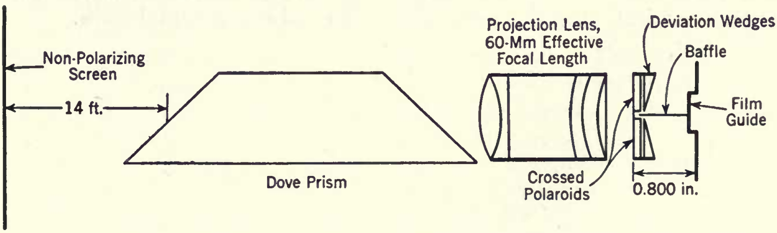


Fig. 5. The projection system. The Dove prism is rotated until the images are vertical on the screen.

edge cuts the ray bundle from the bottom. The illumination is sufficient in this sytem to operate the Fastax camera at 9000 frames/sec, using Linagraph film. Attempts to use the system with Kodachrome film at 500 frames/sec were unsuccessful. In adjusting the system before exposure it was found necessary to view the film directly rather than use the regular Fastax viewer, because the relative aperture of the viewer is smaller than that of the camera lens, thus vignetting some of the rays.

The projector is a Bell & Howell Diplomat, Model A, modified as follows: A two diopter negative lens is combined with the regular 50-mm projection lens to obtain a longer back focal length. Between the lens and the film gate two wedges are mounted as shown in Fig. 5. Also, two crossed polaroids are mounted in front of the wedges and a baffle is placed to isolate each field. A Dove prism is placed in front of the projection lens at such an angle that the images of the flame tube appear vertical on the screen. This is necessary since the observer can see only stereoscopically in the horizontal plane through the eyes. A throw distance of 14 ft is used to a nonpolarizing screen. The observer wears crossed polaroid lenses.

For successful operation of this system, the following points should be carefully considered:

1. Screen registration: This involves careful setting of the images in the Fastax, particularly in the horizontal direction (vertical direction on the screen). It is desirable to use fine wires in the object field and set them to within 0.002 in. in the image field. At the projector, the deviation angle of the prisms, focal length of projection lens and throw distance are all related quantities and should be carefully adjusted.

2. Care should be taken to avoid image jump on the screen. Even though the images may jump together, this causes difficulty in stereoscopic fusing.

For more precise analysis, prints may be made from the film and viewed with a conventional Wheatstone stereoscope using magnification.

Observational Results

The system was tested by using opaque objects such as the hexagonal cylinder which was rotated at high speed. Completely satisfactory pictures were obtained.

Some loss of the depth effect is encountered in viewing symmetrical smooth flame surfaces, as for example, the spherical wave leaving the spark ignition point of Fig. 3a. This effect is probably due to high transparency and lack of contrast.

In turbulent flames or turbulent hot gases, the stereoscopic effect is achieved. If one knows the true scale of the object field, it is possible to locate events along the line of sight, and also determine directions of rotation of the gases.

The author wishes to acknowledge the assistance of R. J. Kraushaar and S. Braunstein with much of the construction and experimental work.

Some Commercial Aspects of a New 16-Mm Intermediate Film Television System

By Raymond L. Garman and Blair Foulds

Theater television requires picture quality comparable to that attained in feature film releases, and flexibility in program scheduling comparable to television broadcasting. A new 16-mm intermediate film system designed for these requirements is described. The system includes video recording equipment for pickup of coaxial-line or broadcast programs, high-intensity film projection equipment, and an automatic rapid film processor. The use of the rapid film processor is discussed in connection with delay techniques for adequate program scheduling. General operating characteristics are analyzed in terms of economics of the system.

Interest in theater television has been growing for a number of years. The past year has seen considerable activity in equipment development along two main lines. One has been the development of 35-mm film delay methods; the other has been the development of better cathode-ray tubes for use with Schmidt optical systems in direct projection.

The 35-mm film delay system has been recognized from the beginning as one which is capable of providing high quality performance. The cost of installation and operation of such a system is understandably high.

The direct projection system offers a possible operating cost advantage but does not, at present, meet all necessary performance requirements. It provides only a marginal amount of light. Additionally, operation of the cathode-ray tube at or near maximum light level is usually accompanied by poor definition in the highlights. The extremely high voltage required by the cathode-ray tube (50 to 80 kv in 1949 practice, with higher voltages in prospect) has been difficult to contain within the equipment and can be expected to result in some erratic component failures unless extreme precautions are taken.

A third system is under development in Switzerland. The details of this system, known as the AFIF Television Projection System,[1] were reported to this Society at its last convention. The system is intermediate in principle between the delay or film recording system and the direct system. It combines some of the features of both systems. Whether or not the system of-

Presented on April 25, 1950, at the Society's Convention at Chicago, Ill., by Raymond L. Garman and Blair Foulds, General Precision Laboratory, Inc., Pleasantville, N. Y.

fers promise for the future remains to be seen.

While these developments have been in progress, a new system has been quietly reaching maturity. This system stems from the 16-mm video recording field, which was an infant in the professional sense a little more than a year ago, and now uses more 16-mm film than all other professional and amateur services combined. The quality of the film produced by video recording has been steadily improved so that today it can be said that if professional equipment is used throughout, from program reception to film projection, theater quality can be attained. The 16-mm film size provides some noteworthy advantages. Cost is considerably reduced over comparable 35-mm systems, and the final product is more easily handled, shipped and stored. A 16-mm video recording system similar to that used in television studios can be engineered for theater service, thus providing an intermediate-film television system. To be successful, however, such a system must be designed for the specific commercial requirements of theater presentation.

System Considerations

Commercial use in theaters calls for quality equipment throughout. Conversion from the television standard rate of 30 frames/sec to the 24-frame/sec rate of the motion picture industry must be performed by a thoroughly reliable method. Particular care is required in design of the many camera and projector details in order to realize fully the resolution capabilities of 16-mm film. Operation must be almost entirely automatic, not only to keep the amount and types of skilled labor to a minimum but also to assure a steady flow of high quality product. Components must be as compact as possible to permit installation within the limited space available in our present day motion picture houses, without occasioning extremely high installation costs. Splicing and editing facilities are needed to allow for insertion of special trailers, titles and show announcements, and to contribute generally to the over-all aspect of showmanship. Processing units must be designed so as to require the minimum amount of chemicals in storage, because of the frequent shutdowns which may be required for program scheduling. The projector itself must be capable of providing adequate light for even the largest motion picture houses and of fully utilizing the performance possibilities of correctly recorded and processed 16-mm sound track. Maintenance cost must be low, and complicated maintenance operations must be avoided wherever possible. In order to meet these severe commercial requirements, new concepts have to be introduced in many or all phases of the art.

Physical Requirements

A better insight into some of the problems can be gained by reviewing the physical requirements of the various units which comprise a complete theater installation. A typical installation, shown in skeleton form in Fig. 1, has terminal facilities for either off-the-air or coaxial-line pickup. The video portion of the program is photographed on 16-mm film from the face of the recording cathode-ray tube, and the accompanying sound is recorded simultaneously on the film sound track. Exposed film from the camera feeds into the rapid film processor and emerges as a dry, waxed print, ready for projection in the special new 16-mm projector designed for the purpose.

The antenna array is the starting point of the system. For theater use, the antenna must provide noise-free operation, freedom from ghosts, and extremely steady signals. This can be achieved by careful selection of the antenna for reception from a particular station or by the use of multiple an-

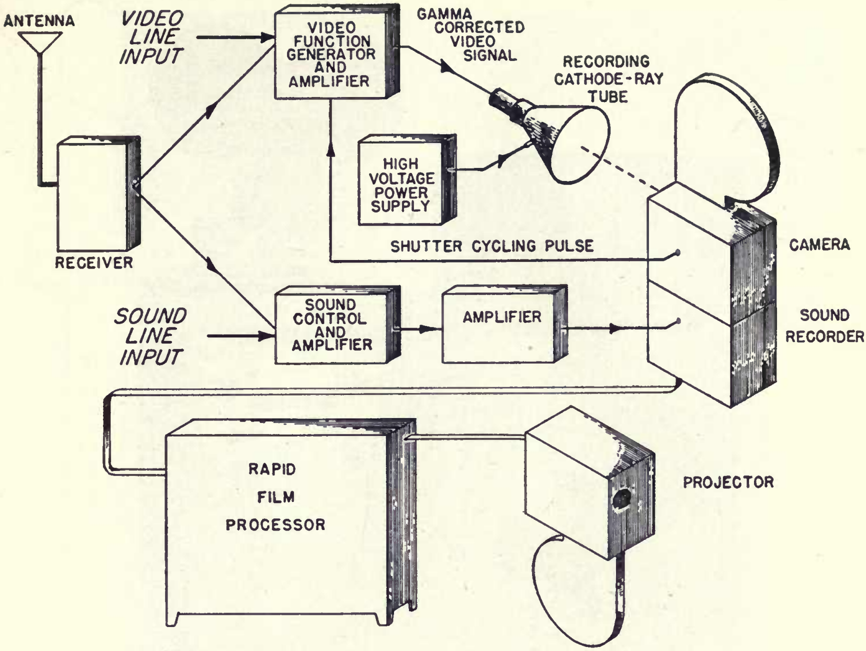


Fig. 1. Block diagram of a 16-mm intermediate film theater television system.

tennas or rotatable antennas if several stations are to be received under severe conditions.

The receiver must be reliable and stable in operation, easy to tune, and simple to maintain. A receiver which provides the necessary reliability and stability has been developed, and it has been described elsewhere in this JOURNAL.[2] By use of remote controls, the receiver unit can be placed in some relatively inaccessible part of the projection booth, or even in some other part of the theater.

Programs can be taken from the receiver or from separate video and sound line inputs. In either case, the video portion of the program feeds into a block which we choose to call the "Video Function Generator." This block consists entirely of electronic circuit elements which perform the various tasks required for conversion of a composite video signal into a picture suitable for photography. It performs the frame-rate conversion from television standard rate of 30 frames/sec to the motion picture standard rate of 24 frames/sec. It provides a gray-range, or gamma correction, and contains control and monitoring facilities. This block can, in fact, be regarded as the heart of the system.

Several blocks, including the video function generator, the 30-kv high-voltage power supply, the recording cathode-ray tube, the camera and the sound circuits are all contained in a single Video Recorder Unit.[3] The unit, shown in Fig. 2, is slightly more than 5 ft wide, and stands 6 ft high to the top of the reel housing. It should be mentioned that, although a double reel housing is shown, only the feed side is used. The reel housing has a 1200-ft capacity, which is equivalent to 33 min of continuous running time. A larger reel housing which holds as much as

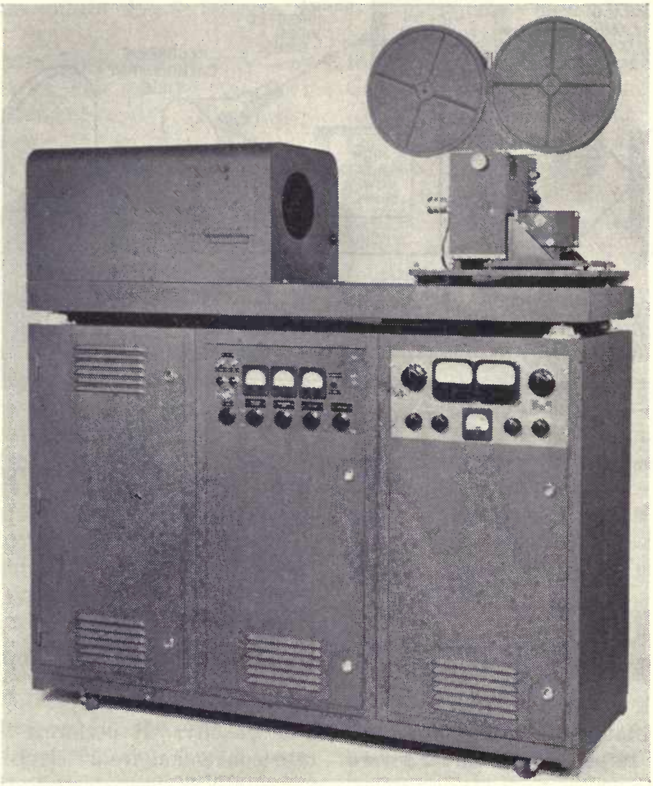


Fig. 2. Video recorder.

4000 ft of film can be installed in place of the 1200-ft one. The hood at the left conceals the recording cathode-ray tube. The electronic circuits associated with the video function generator are contained in the base.

The gray-scale or gamma correction circuit enables a considerable improvement in picture quality over that obtained in an uncorrected system. A gamma of between 1.5 and 1.7 is generally considered to give the most pleasing picture for motion picture exhibition by direct projection. The gamma value actually obtained depends on the over-all transfer characteristic of the system elements which intervene between the scene and the print. Any system element having a nonlinear transfer characteristic affects the gamma value. Amplifying and detecting elements which are commonly used have linear transfer characteristics, but many of the currently available light-to-signal and signal-to-light transducers are inherently nonlinear. Picture contrast in present television practice approaches that of a high-gamma print, due to the nonlinear transfer characteristics of the camera pickup tube and the recording cathode-ray tube. The film itself further increases the final gamma value so that the cumulative effect in an uncorrected system is a higher gamma value than desired. The correction circuit, a nonlinear amplifier with an adjustable characteristic of the type required to reduce print

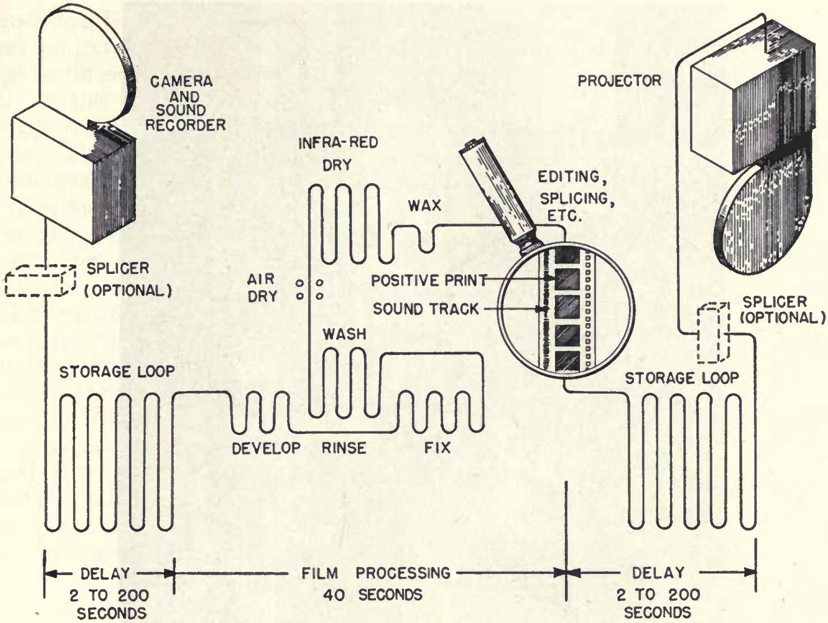


Fig. 3. Film path.

gamma, can be controlled as required to produce an optimum print.

The remaining portion of the video function generator is devoted to the frame rate conversion circuits. The operation of these circuits is based on the fact that each television frame contains exactly 525 horizontal scanning lines. Electronic counting circuits are therefore used to time the film exposure. The operation is as follows:

Film exposure may start at any horizontal scanning line of the television image. Once started, the exposure continues until exactly 525 lines have been counted out. The circuits then blank the recording cathode-ray tube and stop the exposure.

In the camera, film pulldown starts after exposure stops. At the end of $\frac{1}{24}$ sec, both the exposure and film pulldown have been completed. The camera then delivers a cycling pulse which starts a new cycle. Photography is thus performed at a rate of 24 frames/sec, that is, at the rate established by the film camera. A complete television frame is photographed for each film frame, even at rates considerably below 24 frames if required.

The camera has a sufficiently fast pulldown to operate within $\frac{1}{120}$ sec, which is the time interval between the end of the television frame and the start of the next film frame exposure. On the other hand, the camera need not have the usual mechanical shutter. The counter circuits, in effect, form an electronic shutter which has a much greater timing accuracy than a mechanical shutter.

The recording cathode-ray tube presents a negative picture to the camera. Reversal introduced by subsequent processing results in a positive print. The cathode-ray tube operates at about 25 kv, which is considerably less than that required in the direct projection system. This voltage must, however, be closely maintained. In other words,

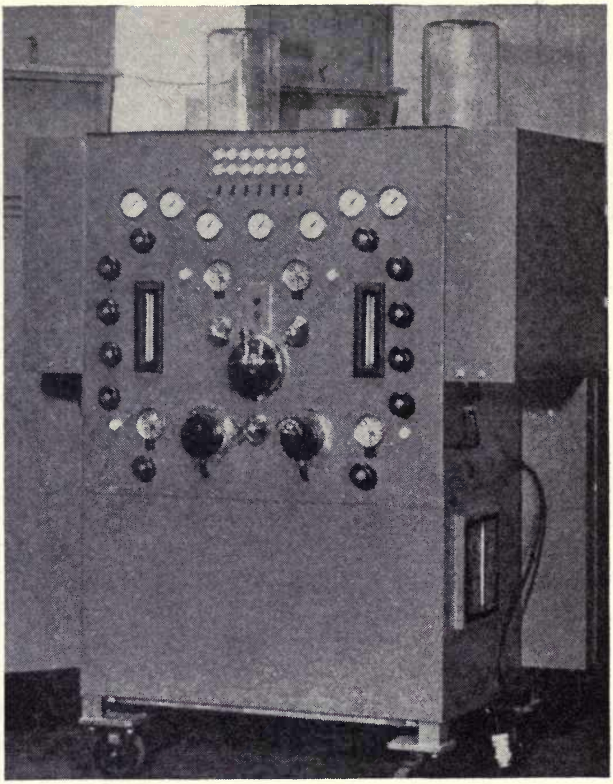


Fig. 4. Rapid film processor.

a "stiff" power supply is needed. Otherwise, the change in beam current due to differences in average scene brightness would cause corresponding changes in both picture size and focus adjustments.

The audio side of the system can and should achieve better than average sound quality. Since playback is from the same film original as that on which the recording is made, only a single recording and playback operation is required. Further, the entire process can be controlled within the theater. If the recording is good, the reproduction can be correspondingly good.

The sound recording head in the system described is one which was developed by J. A. Maurer, Inc. Response is essentially flat to 9 kc. Recordings are high-level variable-density, corrected for both the toe and shoulder of the H&D curve. An intermodulation figure of 6% is obtained, which is comparable with that of the best double-film toe recordings. A network matches the recording characteristic to the playback characteristic of the reproducer. The G.P.L. projector sound head is designed to match the frequency range of the recording head.

The problem of handling the exposed film after it leaves the camera introduces several requirements. Splicing facilities are needed to allow insertion of fill-ins, trailers, titles, and

processing leader, and to permit camera and projector changeover. Film storage facilities are needed to allow any one of the units to be stopped separately while the other units are running. These features are shown in more detailed form in Fig. 3.

Two types of film storage racks are available. One, the larger, has a maximum delay capacity of about 3 min. The other, the smaller, has a maximum delay capacity of about 10 sec and assembles directly to the side of the Rapid Film Processor.[4] The storage loop in the smaller rack is sufficiently long to avoid possible film breakage when adjacent units are simultaneously started or stopped. The larger rack provides sufficient delay for most splicing and editing operations. Racks can be combined for additional delay, if necessary.

A particular advantage of 16-mm film is that it permits the use of relatively compact equipment for film handling and processing. The Rapid Film Processor is only 5 ft high and approximately 3 ft wide (Fig. 4). The larger film storage rack, which contains sufficient footage for 3 min. of running time, occupies a space about 1 ft wide by 6 ft high. It is reasonable to assume that space for these components can be found in or adjacent to most projection booths.

The use of 16-mm film in theaters has previously been limited by the lack of projectors with sufficient light output for the purpose. An arc lamp projector has therefore been developed and made available for theater use. The standard 16-mm arc lamp projector (Fig. 5) provides 2000 total screen lumens when used with an $f/1.6$ lens. With special carbons and feed methods, it may be possible to obtain as much as 3200 total screen lumens. The illumination and screen brightness figures for both types of carbons are shown in Table I. The figures are stated on the basis of shutter running and no film in the gate. The acceptable screen brightness by SMPTE standards, on this same basis, is 9 to 14 foot-Lamberts. It is therefore apparent that illumination is adequate for even fairly large houses. The illumination figures shown may seem surprisingly high for the film size used. However, the average shutter efficiency of 35-mm projectors is in the order of 50%, while the shutter efficiency of the particular 16-mm projector described is 73%. In addition, a larger lens aperture is used with this projector than is commonly used in 35-mm machines.

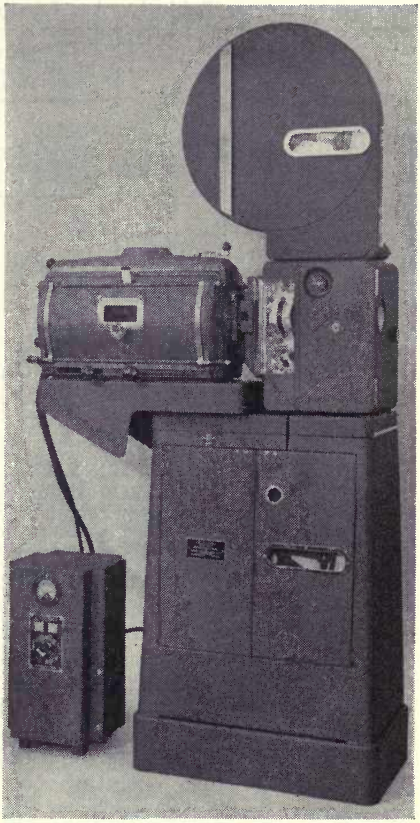


Fig. 5. 16-Mm arc lamp projector.

In regard to operating costs, 16-mm film offers an appreciable advantage

Table I. Arc Lamp Projector Performance

Throw Distance, in feet: 4-In. F.L. Lens	Throw Distance, in feet: 2-In. F.L. Lens	Picture Width, in feet	Standard Arc Lamp for 16-Mm Projector 2000 Total Screen Lumens*: Illumination, foot-candles	Screen Brightness, foot-Lamberts: Matte Screen	Screen Brightness, foot-Lamberts: Beaded Screen‡	Special Arc Lamp for 16-Mm Projector 3200 Total Screen Lumens*: Illumination, foot-candles	Screen Brightness, foot-Lamberts: Matte Screen	Screen Brightness, foot-Lamberts: Beaded Screen
80	40	7.5	47	38	277	76	61	443
100	50	9.5	30	24	175	48	39	281
120	60	11.4	21	17	121	33	27	193
140	70	13.2	15	12	90	25	20	143
160	80	15.2	11	9.1	66	18	15	106
180	90	17.1	9.3	7.5	55	15	12	87
200	100	19.0	7.3	5.9	43	12	9.4	69
220	110	21.0	6.1	4.9	35	9.7	7.8	57
240	120	22.8	5.1	4.1	30	8.2	6.6	48
260	130	24.6	4.4	3.5	26	7.0	5.7	41
280	140	26.6	3.8	3.1	22	6.1	4.9	36
300	150	28.5	3.3	2.6	19	5.2	4.2	31
340	170	32.4	2.5	2.0	15	4.1	3.3	24
400	200	38.0	1.9	1.5	11	3.0	2.4	17

* With shutter running, no film in machine.
‡ When viewed in the direction of the projected beam. When viewed 10° from the projected beam direction, the values are 40% of those listed.

over 35-mm film. Current film prices for fine grain release positives on safety stock are $17.20 per hour for 16-mm film, as against $80.00 per hour for 35-mm film. Other operating costs can also be expected to be lower, but not necessarily in as high a ratio, nor can exact evaluations be made. Chemical costs should be lower with 16-mm film. The greater compactness of 16-mm equipment, and the smaller floor space requirement, may allow a saving in new theater construction cost or, alternately, an increase in useful seating capacity. The life expectancy of 16-mm equipment which is designed for professional use is as high as, or higher than, that of 35-mm equipment. The projector operates at the same frame rate in either case and can therefore be assumed to have the same life expectancy; the processor, operating at a lower film travel rate, can be assumed to have a greater life expectancy. Due to the ease of handling 16-mm film, labor costs may be somewhat lower.

Conclusion

All of the components for intermediate film theater television using 16-mm film size are currently available. This film size offers important cost economies in both hourly operation and initial installations. Delay techniques permit flexibility in program scheduling. Picture quality and screen brightness are entirely satisfactory for theater use.

References

1. "Theater Television," *Jour. SMPE*, vol. 52, pp. 243–272, Mar. 1949. (Appendix, pp. 263–266, describes AFIF Television Projection System.)
2. F. N. Gillette and J. S. Ewing, "Component arrangement for a versatile television receiver," *Jour. SMPTE*, vol. 55, pp. 189–196, Aug. 1950.
3. F. Gillette, G. King and R. White, "Video program recording," *Electronics*, vol. 23, no. 10, pp. 90–95, Oct. 1950.
4. J. S. Hall, A. Mayer and G. Maslach, "A 16-mm. rapid film processor," *Jour. SMPTE*, vol. 55, pp. 27–36, July 1950.

Television Film Recording and Editing

By Albert Abramson

This paper reviews the uses of television film recording and the possibilities of applying the editing principle to it.

There is a need in television for a flexibility and perfection that cannot be attained by using live television techniques. The means for meeting this need lie within the scope of any television station equipped to record television programs on film. But today's methods of television film recording must be improved both filmically and technically.

Cathode-ray photography dates back to 1938. In that year the first attempts were made to photograph the image on the kinescope tube.[1] The low light intensity of the image combined with the use of standard spring-wound cameras gave very unsatisfactory results. The most difficult problem was to synchronize the 30-frame/sec rate of the television screen with the 24-frame/sec rate that is standard motion picture practice. Twenty-four frames per second were necessary in order to use existing projection and sound apparatus. The most critical characteristic in the recording camera is the timing of the shutter blanking and exposure interval.[2] This problem has been solved by means of cameras incorporating specially designed mechanical or electronic shutters.

A contribution submitted on May 31, 1950, by Albert Abramson, Graduate Student, Cinema Dept., University of Southern California, 3441 W. Second St., Los Angeles 4, Calif.

Essentially, a television film recorder consists of this special camera, a monitor which will give precise visual images and a sound recorder to pick up the accompanying sound. At present there are both 16-mm and 35-mm television film recorders with either single or double system sound.

Using 16-mm has the advantage of lower film and processing costs; it is approximately one third as expensive as 35-mm. No marked improvement is to be had by recording on 35-mm rather than 16-mm at the present time. With the use of fine-grain, high-resolution, 16-mm film emulsions, no loss of resolution in recording the television image is noticeable. Using 35-mm has the added disadvantage of very stringent fire regulations and, finally, the cost of 35-mm projection equipment is often prohibitive. As a result, most television stations are using 16-mm film for their recordings[3]; 35-mm film is being used primarily for theater television.

There are four main purposes for which television film recordings can be made at present:

1. *Transcriptions.* The transcription is the main function of television film recordings today. It is a recording of a

complete show either as it goes over the air or as a closed-circuit operation. It may be shown as: (a) *delayed telecast*, to make up for the difference in time zones between the east and west coasts; (b) *repeat telecast*, to catch a larger audience at a more appropriate time; or (c) *syndicated telecast*, in which case it is sent to a station that is not connected by either coaxial cable or microwave relay, and is shown at any convenient time.

2. *Theater television.* Television film recordings are used as an intermediate system of television projection. The program is picked up by receiving equipment at the theater. It is then recorded by 35-mm single system equipment. The signal is inverted and a direct-positive print results. The film is fed into rapid-processing machines where it is processed, dried and fed directly into the projection machine in a little over a minute from the time of exposure. This system allows theaters to show television programs using existing 35-mm projection equipment.[4]

3. *Research.* This includes recordings made for either auditions or previews. Recordings are often made to improve the quality of a program. Techniques of camera work, acting, lighting, set design and all the elements that go into a television show can be checked before the program is to go on the air.

4. *Reference.* There is no better way to keep a record of a television program than to record it as it goes over the air. It is possible that the F.C.C. may require a record kept of every program telecast.

Technically speaking, the quality of television film recording is fairly good and will continue to improve. With certain refinements, such as greater bandwidth and more lines, it should eventually be impossible to distinguish a television film recording from a film shot by a standard motion picture camera.

Dissatisfaction with present television film recording quality has led to the rise of the multicamera motion picture system. In this system a multiple camera setup utilizing three or more standard motion picture cameras is used. All cameras can operate simultaneously. By utilizing live television techniques of dollying and camera movement, the program is covered from a multitude of angles. With the use of an ingenious cuing system the films from the different cameras are later spliced together to form a complete television program.[5] The use of multicamera setups is, of course, not new. They were extensively used some twenty years ago in the early days of sound.[6] This system, at present, gives major-studio quality and as such deserves much merit. Assuming that eventually the quality of television film recording will equal that of standard motion picture practice, the multicamera system will not maintain its superiority over recording through the television camera which has these advantages:

1. The television camera has an enormous advantage over the standard motion picture camera, in that all it "sees" can be viewed instantly. All camera setups can be checked on the monitor for lighting and composition. There is no problem of parallax, focus or exposure. The director knows in advance exactly what the scene will look like. Many a director and cameraman in the major film industry would like to have this tremendous advantage. During the actual performance any mistakes can be seen and immediately reshot. There need be no waiting for "rushes" as there can be no doubt as to the scene's outcome.

2. It allows film to take advantage of the light amplification characteristics of the image orthicon camera. Thus it will be possible to film certain scenes under light conditions that are impossible with the standard motion picture camera.[7] This means the use of

more natural lighting or the use of a minimum of lighting equipment.

3. Certain optical effects such as dissolves, fade-ins, fade-outs, double exposures and background shots can be made in the television cameras themselves. This adds to the economy of the system as it can reduce the cost of producing these special effects optically.

4. It allows the television station to utilize the equipment on hand. Thus the television camera can serve a dual purpose. It can be used for live television programs or it can be used in conjunction with the television film recorder. This allows the station complete control over program content as all programs can be made on the studio premises and conform to the station's needs.

5. Since all recording is accomplished at a central point, it should be easy to keep the recording and developing process under the strictest possible control. The potentialities of a system like this are unlimited and may make the standard motion picture camera as we know it today obsolete.

Filmically speaking, the present-day television film recording leaves much to be desired. It possesses the physical characteristics of motion picture film but lacks the inherent capabilities of the true motion picture, for it is restricted by the limitations of the live television program.

In a live television program a unity of time and space must be observed. Movement is confined by the physical limits of the stage itself. Performers must learn complete scripts. Changes in costume or makeup take time and there must be cover-up action during this period. Even when using two or more sets the performer can travel through them only at a certain speed. Transitions must either be eliminated or filmed in advance. Outdoor sets are seldom if ever used. During the performance any mistake is easily noticed and there is no chance to rectify it. As a result of these restrictions, the average television play today resembles a stage play in that the story is advanced through the dialog. This is good stage technique, but is poor television. Television is a visual medium and as such the story could and should be advanced by visual means. Movement on the screen is interesting and tells its own story. Dialog is important but should never dominate the picture.

Editing

The true motion picture is not just a recording of reality but a rearrangement of that reality to suit its own purposes. Both the standard motion picture camera and the television film recorder are recording mechanisms. They can do nothing but record on film a scene that is placed before their lenses. Then how does the motion picture gain its flexibility and freedom of movement, its ability to manipulate time and space? The answer lies in the editing process. It is in the editing room that the motion picture, as we know it, comes into being.

Here is created filmic time and filmic space. Filmic time and filmic space exist only on the individual strips of motion picture film. Actual events can be stretched or compressed. Time can be made to stand still or to go forward or backward. It is possible to show events, occurring at widely separated points, and simultaneously. Unrelated shots are cut together and meaning is extracted from their juxtaposition. An accident occurs; we see, in rapid succession, the victim crossing the street, the driver's grim look, his foot slam on the brake, the victim's horrified face, the wheels skidding on the pavement, the victim lying in the street. A man steps out of a New York hotel into a South American street. These and many other scenes are possible only through the editing process. These are no *mere* tricks, they are the lifeblood of the visual medium. As a visual medium, television can use the editing principle

to its advantage. This will free television from the limitations imposed upon it by live television techniques.

At the present time, the major networks are editing television film recordings for the following reasons:

1. To make transitions which would otherwise be impossible if the program were recorded straight through.

2. To rerecord imperfect scenes.

3. To eliminate excess footage and edit the show down to required length.

In applying the editing principle to television film recording, it is well to note a major difference between the motion picture and television. Both, being visual mediums, have the shot as their foundation. However, the motion picture is filmed on a single-shot basis whereas television is set up on a multiple-shot basis. This is no handicap; quite the contrary, it can be used to great advantage.

In the motion picture each individual shot is arranged for maximum effect. There is always one certain camera angle that will be most effective depending upon what idea is being conveyed to the audience. Thus each scene is carefully arranged to put across this idea. Therefore, even the same scene when photographed from different angles will be rearranged to suit each individual shot even though all of these shots will be cut together to create a seemingly continuous scene.

This is not necessary in television, for the use of multiple cameras combined with electronic cutting makes it possible to get a variety of shots without making new setups for each individual shot. This can be done by careful planning of camera angles, the use of proper focal length lenses and the use of lighting to suit the scene. Here, of course, the maximum effect from each shot or cut is not as assured as in the single-shot setup, but such should be nearly attained. Thus it is possible to create a maximum number of shots with a minimum number of setups for any given scene. It is proposed to use this type of multicamera setup wherever the action will allow it.

In order to apply the editing principle to television film recording, preproduction planning is the first necessity. In addition to planning details of sets, costumes, props, etc., the script must be broken down into two types of sequences. The first type of sequence should consist of that kind of scene where two or more television cameras can be used for the necessary variety of shots. This type of scene will be recorded as a unit making full use of electronic cutting.

The second type of sequence should consist of that kind of scene where it is necessary to stop the recorder to make changes in lighting, costumes, sets, makeup, etc. This can be recorded with a multi-camera setup or, if circumstances demand, with only one camera.

In all instances, the various sequences will be recorded in whatever order is most practical. By minute scheduling of operations it should be possible to record the various sequences in the shortest amount of time. After processing, the recorded sequences can then be edited into a smooth, flexible program with a minimum of time and effort. The cost should approximate straight television film recording with the quality equaling that of professional motion picture practice.

This is a process in which we are utilizing the best features of motion pictures and television. We have given the television camera a memory. We have taken the unique picture-control elements of the television camera and added the permanency, flexibility and perfection of motion picture film. Thus the process is one that is peculiar to neither motion pictures nor television alone, but is a synthesis of the two that can be used to their mutual advantage.

It has been said that television will lose its sense of "immediacy" through

the use of television film recordings. It has also been said that the public likes to know that the program being telecast is being presented at that very moment. This all depends upon the type of program being considered. Every day millions of persons attend motion pictures that are from nine to twelve months old before being released. Even the earliest 'newsreels' are from a few days to several months old when being presented.

"Immediacy" is determined by program content. Obviously, no other medium is as well equipped to present an event as it actually happens as television. In reporting spot news, sport events, presidential elections and other events of great public interest, television can present these programs to the public as they actually occur. To this list can be added programs of a semirehearsed nature such as vaudeville, comedy or variety shows. However, rehearsed programs, especially drama of all varieties, need the perfection and flexibility that only a filmic use of the television film recorder can give them. There is no reason why drama should be presented live. The perfection and flexibility that can be had by this method mean better dramatic programs and that is our ultimate goal.

This is where the future of television film recording lies and it doesn't interfere with any type of program in which "immediacy" is its most important aspect. To the contrary, it can record those programs of lasting interest and preserve them for posterity.

References

1. R. M. Fraser, "Motion picture photography of television images," *RCA Rev.*, vol. 9, pp. 202–217, June 1948.
2. Thomas T. Goldsmith, Jr. and Harry C. Milholland, "Television transcription," *Electronics*, vol. 21, pp. 68–71, Oct. 1948.
3. Report of the Television Committee, "Films in television," *Jour. SMPE*, vol. 52, pp. 363–383, Apr. 1949.
4. Richard Hodgson, "Theatre television system," *Jour. SMPE*, vol. 52, pp. 540–548, May 1949.
5. Jerry Fairbanks, "Motion picture production for television," *Jour. SMPTE*, vol. 55, pp. 567–575, Dec. 1950.
6. F. Green, *The Film Finds its Tongue*, p. 67, G. P. Putnam, New York, 1929.
7. Thomas T. Goldsmith, Jr. and Harry C. Milholland, "Television transcription by motion picture film," *Jour. SMPE*, vol. 51, pp. 107–117, Aug. 1948.

ABSTRACT

The Genlock–A New Tool for Better TV Programming

By John H. Roe

Recently, the need for more and better techniques in video programming has become more and more apparent, particularly as picture quality has improved, thus focusing attention on ideas for adding some of the finer touches. One of the gaps in the present programming structure arises from the lack of synchronization between two distinct program sources which may supply successive parts of a program. The field-frequency pulses may be phased together by manual adjustment and they will stay so as long as the same power source is the reference for both generators, but there is no such simple solution to the problem of phasing the line-frequency pulses.

Lack of tight lock-in between two such systems results in several programming limitations. For example, when the program line is switched from one system to the other, the receivers have to adjust themselves to the new synchronizing signal. The horizontal (line-frequency) scanning changes very quickly in most cases, but the vertical (field-frequency) scanning circuits have much more inertia and do not respond quickly. The usual result is, therefore, that the picture on a receiver will "roll over," much to the annoyance of the viewer.

Another limitation is the impossibility of using lap-dissolves and superpositions involving pictures from two unrelated television pickup systems. The increasing use of lap-dissolves and superpositions in studio programs makes it seem more and more desirable to provide means to produce the same effects at all times regardless of the sources of the signals to be treated. To make them possible, the synchronizing signal generators must be locked together tightly, field for field and line for line, just as though the whole system were operating on one generator instead of two.

The most direct solution to this problem is to provide means for locking the local synchronizing signal generator, as a slave, to the remote generator, as a master. Once the equipment for this control of the local generator is functioning, the remote signals may be treated as local signals in any of the common types of switching transitions and superpositions, thus making it possible to go back and forth from one source to the other without concern as to the point of origination.

Foreseeing the need and the demand for simple, automatic and foolproof means for tying two television pickup systems together, RCA engineers have developed a device called the Genlock, which accomplishes the desired lock-in automatically without any manual phasing adjustment whatever.

Abstract by Pierre Mertz of a paper presented on September 26, 1950, at the National Electronics Conference at Chicago, Ill. (in which the SMPTE Central Section participated), by John H. Roe, Radio Corporation of America, RCA Victor Div., Camden, N.J. The complete paper will be published in *Proceedings of the National Electronics Conference*, vol. 6 (for 1950).

The Genlock

The Genlock is a unit which combines two separate circuits which serve to provide control signals to the line-frequency and field-frequency sections, respectively, of the local synchronizing signal generator.

The first consists of an automatic frequency-control discriminator which derives a varying d-c error signal from the comparison of the horizontal driving signal (from the local synchronizing signal generator) with the separated synchronizing signal derived from the remote picture signal. This latter synchronizing signal must be separated from the composite picture signal in some other equipment such as the RCA TA-5C stabilizing amplifier. No separator circuit is provided in the Genlock. The error signal is applied to the reactance tube in the local synchronizing signal generator, thus directly controlling the frequency and phase of the master oscillator. The control is rigid, allowing no perceptible horizontal drift or instability between the two pictures.

The second circuit compares the synchronizing signals, one from the local synchronizing signal generator and the other from the synchronizing signal separator operating on the remote picture signal, and from this comparison derives an error signal in the form of a positive pulse recurring at field frequency. As long as the two field-frequency signals are out of phase, the pulse exists, but as soon as they become coincident, the error pulse ceases to exist. The error signal is applied to the 7:1 counter circuit in the local synchronizing signal generator (RCA TG-1A or TG-10A) in such a way as to cause it to miscount. As long as the error signal continues to recur, the local field frequency drifts at an accelerated pace causing the two signals to approach in phase. At the instance of coincidence the error signal disappears and the counter circuit begins to operate normally. Thereafter the two signals remain in phase as long as the Genlock continues to function.

The operation of the line-frequency control circuit is quite rapid so that lock-in of the horizontal scanning circuits appears to be almost instantaneous. The field-frequency control circuit, however, requires a variable amount of time to assume full control depending on the initial phase difference between the two signals. Phase shift brought about by the control occurs at a definite rate of three scanning lines per field. The maximum time required to achieve control is about 1.46 sec.

The Genlock never requires more than one field to bring the field-frequency pulses into phase. The reason is that when it causes the counter in the synchronizing signal generator to miscount, it is possible, under the proper conditions, to bring about a conversion of an "even" to an "odd" field, or vice versa.

The question may arise as to what happens if by some mischance the even field in one system is brought into coincidence with the odd field of the other system. The answer is that nothing serious takes place. The tops and bottoms of the two pictures are slightly displaced under such conditions.

From a practical point of view, it is not important to have exact coincidence of the top and bottom lines, respectively, in the two picture signals. Any lack of coincidence means simply that the edges of the two vertical blanking signals are slightly separated in time, and therefore, in space, on the picture tube. This results in a shift up or down, of the top and bottom of the raster at the time of switching by an amount proportional to the discrepancy. If the discrepancy is, for example, only one or two half-line intervals, the shift is almost impercep-

tible. In the average receiver it is hidden behind the mask and is not visible at all.

Thus it may be seen that the Genlock is entirely automatic in operation, and requires only the proper information in the form of suitable signals to bring about a solid "marriage" of the two synchronizing signal systems. The only control necessary is a switch for disconnecting the normal frequency reference standard and at the same time connecting the output of the Genlock to the proper circuits in the local synchronizing signal generator.

System Considerations

Two methods of using the Genlock in a television station are suggested. In the first case, where only one synchronizing signal generator is available at the studio, the connections between it and the Genlock are made through a switch. In the second case, where an additional or standby synchronizing signal generator is available at the studio, the Genlock is used to control the standby generator, and the system is transferred to Genlock operation by switching from one generator to the other. This is the preferable method because it permits previewing of Genlock operation before the system is transferred.

In either case, because a transfer in or out of Genlock operation causes a transient disturbance in the operation of deflection circuits in receivers, it is desirable to make the transfer with the video output of the station faded down to black.

Inasmuch as the Genlock makes the local station dependent on a signal source which is remote and beyond the control of local operators, it is interesting to know what happens when the remote signal fails. The Genlock is so designed that, when the remote signal is lost, the local synchronizing signal generator continues to operate quite normally at a rate which is very close to that existing under Genlock control. In other words, the synchronizing signal generator becomes free-running, depending only on the stability of its master oscillator. When the remote signal is restored, the Genlock regains control in the same way as when initially put into operation.

Acknowledgment: Credit is due to F. W. Millspaugh and A. H. Turner, who contributed much to the development of this device, and to Dr. H. N. Kozanowski, under whose direction the work was done.

Standards

Standards Symbol Changed to PH

It has been ASA's practice to designate each related group of its various activities with a single letter symbol. The letter "Z" was reserved for those "miscellaneous" committees not considered large enough to warrant assignment of a separate symbol. The 30-year old Section Committee on Photography, Z38, has been in that category along with Sectional Committee on Motion Pictures Z22.

Phenomenal growth of interest in photographic standards in recent years has so expanded Z38 that it became too large to function efficiently under its old organization, so ASA and the committee members agreed to certain essential changes. Z38 was divided into four separate committees, which together with Z22 were then placed under the administration of a newly established Photographic Standards (Correlating) Committee. A new letter designation was established to cover the entire group. In view of the imminent need for a double-letter code system, the letter P, first proposed because it had not been used before, was expanded to PH and is now the common symbol for all sectional committees on photography. ASA has officially assigned the following designations to the following committees:

PH1	Films, Plates and Papers
PH2	Photographic Sensitometry
PH3	Photographic Apparatus
PH4	Photographic Processing
PH22	Motion Pictures

These changes in no way affect the scope or membership of the Sectional Committee on Motion Pictures, but change only the code numbers on all new standards. The first proposed standards to carry the new numbers follow in this issue.

Cutting and Perforating 32-Mm Film

Two Approved American standards for cutting and perforating 32-mm film appear on the following pages. These standards were first published in the February, 1949, Journal as proposals to elicit comments or criticisms. Since no adverse criticism was received, they were processed through the required channels and officially approved on October 6, 1950.

Although film of this type has been used commercially since 1934, there never has been a formal standard. During the intervening years a number of changes have been made in the dimensions. Debrie, who was the originator of the slit-film process for release printing, was aware that slitting of 32-mm film into two 16-mm widths might be inaccurate. This inaccuracy would make one half wider than the other half, and could cause trouble in the projector gate. Therefore, he made the original French film narrower than twice the width of 16-mm film. The first French film was about 1.252 in. in width. Manufacturers in this country made film of this width for some time but later

widened it by 0.005 in. to make it 1.257 in.

It appears that there have been four or five slightly different styles of perforating in use at various times. Values currently adopted for film width and for transverse pitch of the perforations are believed to be acceptable to all manufacturers. Differences between the present standards and the earlier dimensions are so slight, it is doubtful that the users can perceive them. Dimensions of the perforation, longitudinal pitch, and the like, are the same as those of current 16-mm film. Dimensioning of the drawings is consistent with the standards for 16-mm raw stock (Z22.5-1947 and Z22.12-1947).

16-Mm Projection Reels

Publication in the February, 1950, Journal of a proposed complete revision of the American Standard for 16-Mm Projection Reels, Z22.11-1941, resulted in a number of comments. Consideration of these comments by the 16-Mm and 8-Mm Motion Pictures Committee, which developed this proposal, has led to recommendation of changes in dimensions R, S, and T, and in Note 7 (formerly Note 3). Although not apparent on the surface, the intent of these changes is to make possible the design of plastic reels within the standard dimensions. Because of the nature of these changes, the Standards Committee agreed that the revised proposal, as it appears on the following pages, should be republished for ninety days trial and criticism. Please send comments to Henry Kogel, Staff Engineer at Society Headquarters, before June 1, 1951.

Projection Lamps

Proposed standards for two types of projection lamps, developed by the 16-Mm and 8-Mm Motion Pictures Committee, appear on the following pages. They are published here for trial and criticism for a period of ninety days. Please forward any comments to Henry Kogel, Staff Engineer at Society headquarters, by June 1, 1951.

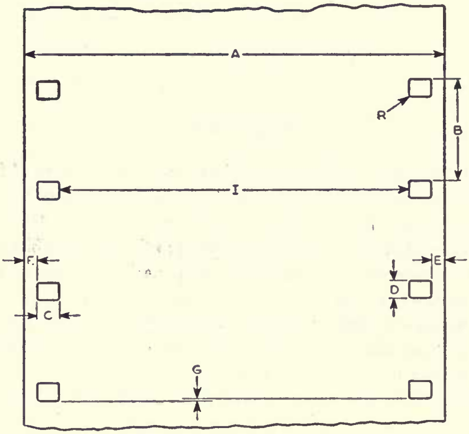
The first of these two proposals, PH 22.84, is entitled Dimensions for Projection Lamps, Medium Prefocus Ring Double-Contact Base-Up Type for 16-Mm and 8-Mm Motion Picture Projectors. It shows a type of base developed recently to provide improved filament positioning, better cooling, and easier replacement with the objective of making the lamp compatible with other recently refined projector elements. In a way, this design has been an ideal subject for standardization in that it is not yet in widespread use and consequently, once the general scheme was agreed upon, the Committee did not have to compromise because of existing practices. The base covered by the proposal is the subject of a patent assigned to the General Electric Company. However, after a search by the Society disclosed no other active patents on pertinent bases, rings or sockets, the General Electric Company agreed to dedicate this patent to the public, clearing the way for standardization.

The second proposed standard is for Dimensions for Projection Lamps, Medium Prefocus Base-Down Type for 16-Mm and 8-Mm Motion Picture Projectors, PH22.85. It will be recognized that lamps of this design have been in general use for many years; however, there has been no American Standard for the dimensions.

American Standard

Cutting and Perforating Dimensions for 32-Millimeter Sound Motion Picture Negative and Positive Raw Stock

ASA
Reg. U. S. Pat. Off.
PH22.71 — 1950
(Z22.71 — 1950)
*UDC 778.534.4



Dimensions	Inches	Millimeters
A	1.257 ± 0.001	31.93 ± 0.025
B*	0.300 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
I	1.041 ± 0.002	26.44 ± 0.05
L**	30.00 ± 0.03	762.00 ± 0.76
R	0.010 ± 0.001	0.25 ± 0.025

These dimensions and tolerances apply to the material immediately after cutting and perforating.

* In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 inch and should be as much smaller as possible.

** This dimension represents the length of any 100 consecutive perforation intervals.

Approved October 6, 1950, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

American Standard

Cutting and Perforating Dimensions for 32-Millimeter Sound Motion Picture Negative and Positive Raw Stock

ASA
Reg. U.S. Pat. Off.
PH22.71 – 1950
(Z22.71 – 1950)

Appendix

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

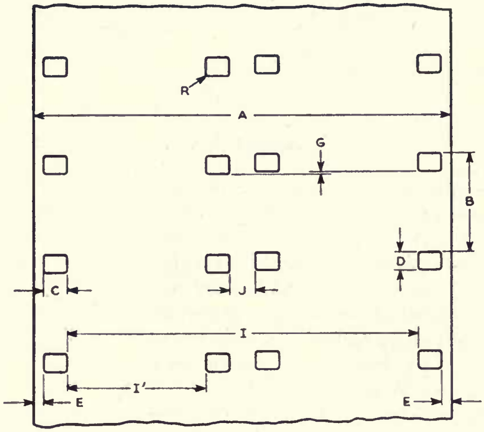
Thirty-two-millimeter release print stock is slit, after printing and developing, to 16-mm width. Since a possible error is involved in this slitting, the width of 32-mm film is made 0.001 inch narrower than twice the width of standard 16-mm film. This narrowing gives a tolerance of 0.001 inch in this secondary slitting operation. If the error of slitting exceeds this tolerance, one of the 16-mm halves may exceed the width allowed for 16-mm film and cause interference in the gate of a projector. In addition to errors of centering, there are errors caused by recurring variations in width. These errors will cause weave on the screen even though the maximum width of the film may not be great enough to cause interference in the projector gate.

American Standard

Cutting and Perforating Dimensions for 32-Millimeter Silent Motion Picture Negative and Positive Raw Stock

ASA
Reg. U. S. Pat. Off.
PH22.72 – 1950
(Z22.72 – 1950)

*UDC 778.5



Dimensions	Inches	Millimeters
A	1.257 ± 0.001	31.93 ± 0.025
B*	0.300 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
I	1.041 ± 0.002	26.44 ± 0.05
I'	0.413 ± 0.001	10.490 ± 0.025
J	0.071 ± 0.001	1.803 ± 0.025
L**	30.00 ± 0.03	762.00 ± 0.76
R	0.010 ± 0.001	0.25 ± 0.025

These dimensions and tolerances apply to the material immediately after cutting and perforating.

* In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 inch and should be as much smaller as possible.

** This dimension represents the length of any 100 consecutive perforation intervals.

Approved October 6, 1950, by the American Standards Association, Incorporated

Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Appendix

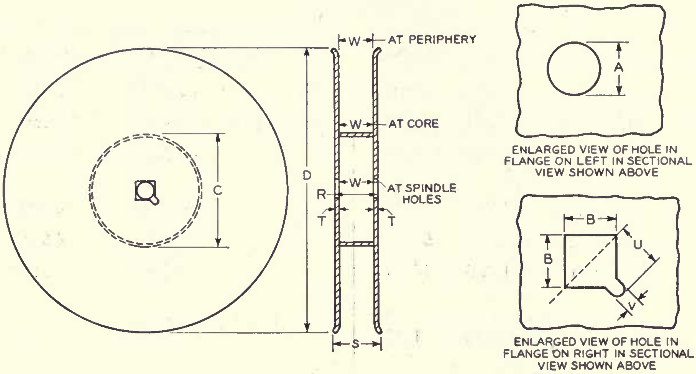
The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Thirty-two-millimeter release print stock is slit, after printing and developing, to 16-mm width. Since a possible error is involved in this slitting, the width of 32-mm film is made 0.001 inch narrower than twice the width of standard 16-mm film. This narrowing gives a tolerance of 0.001 inch in this secondary slitting operation. If the error of slitting exceeds this tolerance, one of the 16-mm halves may exceed the width allowed for 16-mm film and cause interference in the gate of a projector. In addition to errors of centering, there are errors caused by recurring variations in width. These errors will cause weave on the screen even though the maximum width of the film may not be great enough to cause interference in the projector gate.

Proposed American Standard	
16-Millimeter Motion Picture Projection Reels (Second Draft)	PH22.11 (Z22.11)



ENLARGED VIEW OF HOLE IN FLANGE ON LEFT IN SECTIONAL VIEW SHOWN ABOVE

ENLARGED VIEW OF HOLE IN FLANGE ON RIGHT IN SECTIONAL VIEW SHOWN ABOVE

TABLE 1

Dimension	Inches	Millimeters
A	0.319 $^{+0.000}_{-0.003}$	8.10 $^{+0.00}_{-0.08}$
B	0.319 $^{+0.000}_{-0.003}$	8.10 $^{+0.00}_{-0.08}$
R[1]	0.790 maximum	20.06 maximum
S[2] (including flared, rolled, or beveled edges)	0.962 maximum	24.43 maximum
T (adjacent to spindle)	0.027 minimum 0.066 maximum	0.69 minimum 1.68 maximum
U	0.312 ±0.016	7.92 ±0.41
V	0.125 $^{+0.005}_{-0.000}$	3.18 $^{+0.13}_{-0.00}$
W, at periphery[3]	0.660 $^{+0.045}_{-0.025}$	16.76 $^{+1.14}_{-0.64}$
at core[4]	0.660 ±0.010	16.76 ±0.25
at spindle holes	0.660 ±0.015	16.76 ±0.38
Flange and core concentricity[5]	±0.031	±0.79

See Notes on p. 3.

NOT APPROVED

Proposed American Standard

16-Millimeter Motion Picture Projection Reels

(Second Draft)

PH22.11

(Z22.11)

TABLE 2

Capacity	Dimension	Inches	Millimeters	Capacity	Dimension	Inches	Millimeters
200 Feet[6]	D, nominal	5.000	127.00	1200 Feet	D, nominal	12.250	311.15
(61 Meters)	maximum	5.031	127.79	(366 Meters)	maximum	12.250	311.15
	minimum	5.000	127.00		minimum	12.125*	307.98*
	C, nominal	1.750	44.45		C, nominal	4.875	123.83
	maximum	2.000*	50.80*		maximum	4.875	123.83
	minimum	1.750	44.45		minimum	4.625*	117.48*
	Lateral run-out,[7] maximum	0.570	1.45		Lateral run-out,[7] maximum	0.140	3.56
400 Feet[6]	D, nominal	7.000	177.80	1600 Feet	D, nominal	13.750	349.25
(122 Meters)	maximum	7.031	178.59	(488 Meters)	maximum	14.000*	355.60*
	minimum	7.000	177.80		minimum	13.750	349.25
	C, nominal	2.500	63.50		C, nominal	4.875	123.83
	maximum	2.500	63.50		maximum	4.875	123.83
	minimum	1.750*	44.45*		minimum	4.625*	117.48*
	Lateral run-out,[7] maximum	0.080	2.03		Lateral run-out,[7] maximum	0.160	4.06
800 Feet	D, nominal	10.500	266.70	2000 Feet	D, nominal	15.000	381.00
(244 Meters)	maximum	10.531	267.49	(610 Meters)	maximum	15.031	381.79
	minimum	10.500	266.70		minimum	15.000	381.00
	C, nominal	4.875	123.83		C, nominal	4.625	117.48
	maximum	4.875	123.83		maximum	4.875	123.83
	minimum	4.500*	114.30*		minimum	4.625	117.48
	Lateral run-out,[7] maximum	0.120	3.05		Lateral run-out,[7] maximum	0.171	4.34

NOT APPROVED

Proposed American Standard

16-Millimeter Motion Picture Projection Reels

(Second Draft)

PH22.11

(Z22.11)

NOTES

* When new reels are designed, or when new tools are made for present reels, the cores and flanges should be made to conform, as closely as practicable, to the nominal values in the above table. It is hoped that in some future revision of this standard the asterisked values may be omitted.

[1] The outer surfaces of the flanges shall be flat out to a diameter of at least 1.250 inches.

[2] Rivets or other fastening members shall not extend beyond the outside surfaces of the flanges more than 1/32 inch (0.79 millimeters) and shall not extend beyond the over-all thickness indicated by dimension S.

[3] Except at embossings, rolled edges, and rounded corners, the limits shown here shall not be exceeded at the periphery of the flanges, nor at any other distance from the center of the reel.

[4] If spring fingers are used to engage the edges of the film, dimension W shall be measured between the fingers when they are pressed outward to the limit of their operating range.

[5] This concentricity is with respect to the center line of the hole for the spindles.

[6] This reel should not be used as a take-up reel on a sound projector unless there is special provision to keep the take-up tension within the desirable range of 1½ to 5 ounces.

[7] Lateral runout is the maximum excursion of any point on the flange from the intended plane of rotation of that point when the reel is rotated on an accurate, tightly fitted shaft.

APPENDIX

Dimensions A and B were chosen to give sufficient clearance between the reels and the largest spindles normally used on 16-millimeter projectors. While some users prefer a square hole in both flanges for laboratory work, it is recommended that such reels be obtained on special order. If both flanges have square holes, and if the respective sides of the squares are parallel, the reel will not be suitable for use on some spindles. This is true if the spindle has a shoulder against which the outer flange is stopped for lateral positioning of the reel. But the objection does not apply if the two squares are oriented so that their respective sides are at an angle.

For regular projection, however, a reel with a round hole in one flange is generally preferred. With it the projectionist can tell at a glance whether or not the film needs rewinding. Furthermore, this type of reel helps the projectionist place the film correctly on the projector and thread it so that the picture is properly oriented with respect to rights and lefts.

The nominal value for W was chosen to provide proper lateral clearance for the film, which has a maximum width of 0.630 inch. Yet the channel is narrow enough so that the film cannot wander laterally too much as it is coiled; if the channel is too wide, it is likely to cause loose winding and excessively large rolls. The tolerances for W vary. At the core they are least because it is possible to control the distance fairly easily in that zone. At the holes for the spindles they are somewhat larger to allow for slight buckling of the flanges between the core and the holes. At the periphery the tolerances are still greater because it is difficult to maintain the distance with such accuracy.

Minimum and maximum values for T, the thickness of the flanges, were chosen to permit the use of various materials.

The opening in the corner of the square hole, to which dimensions U and V apply, is provided for the spindles of 35-millimeter rewinds, which are used in some laboratories.

D, the outside diameter of the flanges, was made as large as permitted by past practice in the design of projectors, containers for the reels, rewinds, and similar equipment. This was done so that the values of C could be made as great as possible. Then there is less variation, throughout the projection of a roll, in the tension to which the film is subjected by the take-up mechanism, especially if a constant-torque device is used. Thus it is necessary to keep the ratio of flange diameter to core diameter as small as possible, and also to eliminate as many small cores as possible. For the cores, rather widely separated limits (not intended to be manufacturing tolerances) are given in order to permit the use of current reels that are known to give satisfactory results.

NOT APPROVED

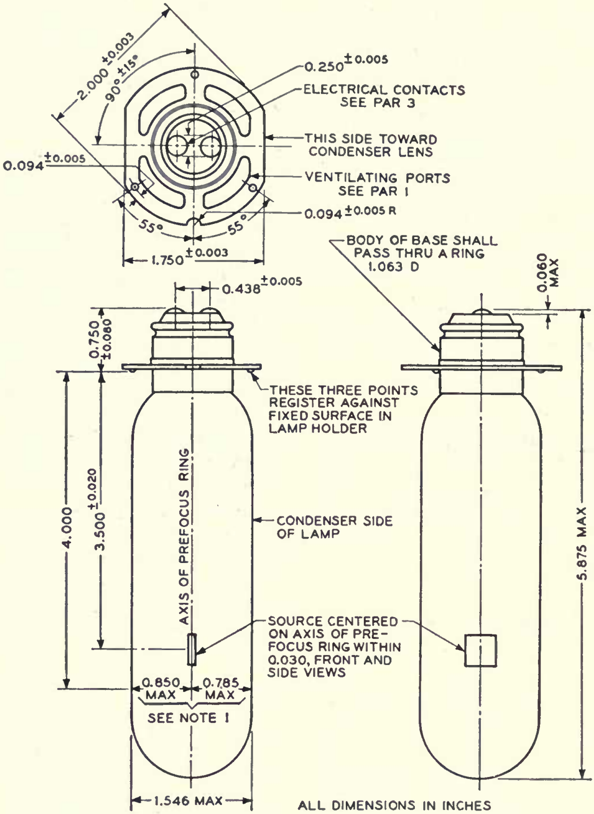
Proposed American Standard

Dimensions for Projection Lamps

Medium Prefocus Ring Double-Contact Base-Up Type

for 16-Mm and 8-Mm Motion Picture Projectors

PH22.84



ALL DIMENSIONS IN INCHES

1. Scope. The purpose of this standard is to establish, for the type of lamp shown, the dimensions essential to interchangeability of lamps in projectors. It is not intended to prescribe either operating characteristics or details of design such as the shape of the ventilation ports or method of attachment of the prefocus ring to the base.

2. Operating Position. Lamps of this type are intended to be burned with the axis in an essentially vertical position, and with the base at the top.

NOT APPROVED

Proposed American Standard Dimensions for Projection Lamps Medium Prefocus Ring Double-Contact Base-Up Type for 16-Mm and 8-Mm Motion Picture Projectors	PH22.84

3. Electrical Contacts. The drawing indicates the area which the electrical members of the lamp holder should contact. It is not intended to dictate the shape of the terminals on the lamp. With lamps of this type, the prefocus ring is not an electrical contact.

Note 1. These dimensions define the maximum excursion of the bulb surfaces from the base axis toward the condensing lenses and the mirror at the points indicated when the lamp is inserted in a holder which rotationally positions the lamp as shown in the end view of the base. Condensing lenses, the mirror, and their mounts must therefore be so located as to insure adequate clearance between these parts and the bulb surface.

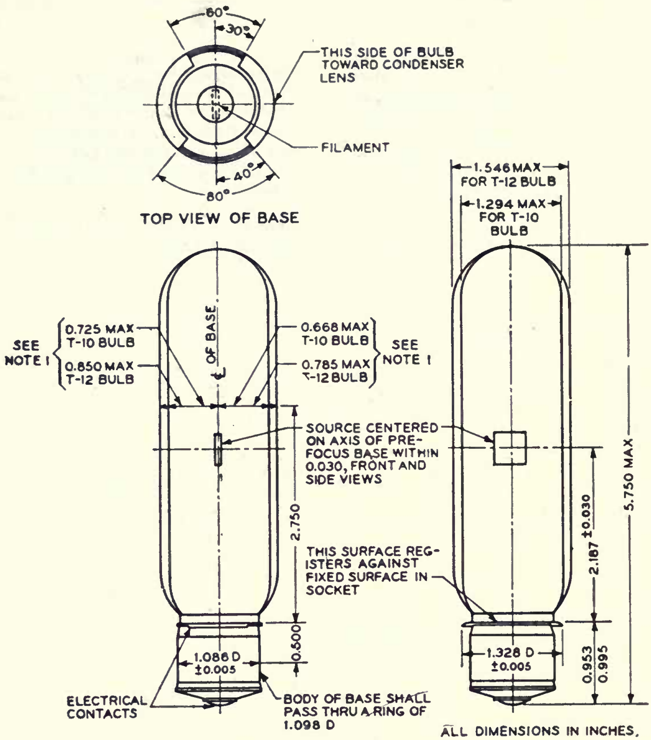
Note 2. For medium prefocus base-down projection lamps, see PH22.85.

NOT APPROVED

Proposed American Standard

Dimensions for Projection Lamps Medium Prefocus Base-Down Type for 16-Mm and 8-Mm Motion Picture Projectors

PH22.85



1. Scope. The purpose of this standard is to establish, for the type of lamp shown, the dimensions essential to interchangeability of lamps in projectors. It is not intended to prescribe either operating characteristics or details of design.

2. Operating Position. Lamps of this type are intended to be burned with the axis in an essentially vertical position, and with the base at the bottom.

Note 1. These dimensions define the maximum excursion of the bulb surfaces from the base axis toward the condensing lenses and the mirror at the points indicated when the lamp is inserted in a holder which rotationally positions the lamp as shown in the end view of the base. Condensing lenses, the mirror, and their mounts must therefore be so located as to insure adequate clearance between these parts and the bulb surface.

Note 2. For medium prefocus ring double-contact base-up projection lamps, see PH22.84.

NOT APPROVED

69th Semiannual Convention

Papers for presentation at the Spring Convention at the Statler Hotel in New York, April 30–May 4, are now being assembled by the 1951 Papers Committee. Committee appointments were completed in early February. The six Vice-Chairmen and all committee members are listed below. Members who wish to make a presentation at this convention or who know of developments which should be reported on promptly are requested to correspond directly with the proper Papers Committee Vice-Chairman. Each of these Vice-Chairmen has available copies of the present Author's Forms, "Hints to Authors" (which suggests appropriate ways of manuscript preparation) and copies of American Standard Z38.7.19-1950 Dimensions of Lantern Slides. Be sure to contact your Papers Committee member promptly, for an early publication date for the Tentative Program has been established. It is essential that these deadlines be maintained so that members whose attendance at the convention depends upon the presentation of technical material in their own fields may be able to make their plans.

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M. G. Townsley, Bell & Howell, 7100 McCormick Rd., Chicago 45, Ill.

Board of Governors Meeting

Progress was the keynote of the Annual Meeting of the Society's Board of Governors held in New York on January 24. The Chairman was Peter Mole, Society President, who took office the first of this year.

The Board first reviewed the Society's business, technical and publications activities for the year 1950, hearing reports by several officers. Since Ralph B. Austrian, Financial Vice-President was unable to attend the meeting, Frank E. Cahill, Treasurer, presented the report of business activities and a summary of the financial status of the Society as of December 31, 1950. His analysis of operations showed that 1950 was the Society's busiest year but that although the Society's income was up, administrative expenses were down, being actually slightly lower than the previous year.

ENGINEERING

Technical activities were reported by Fred T. Bowditch, Engineering Vice-President. Among the items which he reviewed was the much discussed question of whether the Society should or should not formally request that the American Standards Association send out a call for a meeting of technical committee TC–36, Cinematography, of the International Standardization Organization (ISO). Such a meeting had been proposed for this coming summer in Switzerland and it was felt that the Society's position of responsibility in this connection made a prompt decision mandatory. After soliciting the opinions of several Society members who had been seriously interested in standards on an international basis for many years, the Board of Governors concluded that calling such a meeting at this time would be quite inefficient and would represent considerable waste of time and money because no specific agenda had been developed. The Board did recommend, however, that vigorous attention be given to the international standards picture by the ASA Sectional Committee on Motion Pictures and by our own standards and technical committees. A responsible agenda could doubtless be developed in time for the ISO meetings already scheduled for 1952 in the United States.

The Board voted sponsor approval of three proposed American Standards which subsequently require the approval of

ASA's Photographic Standards (Correlating) Committee and also of the ASA Board of Review. They cover Dimensions for 32/35-mm Negative Stock; Focus Base Point for 16- and 8-mm Cameras; and Threads and Flange Distances for 16- and 8-mm Camera Lenses.

PUBLISHING

Since neither Clyde R. Keith, former Editorial Vice-President, nor John G. Frayne, Editorial Vice-President for 1951–52, was able to attend the meeting, their written reports were offered by the Secretary. Mr. Frayne announced reappointment of Arthur C. Downes as Chairman of the Board of Editors, and observed that the Society was particularly fortunate in having had such a capable engineer take a great personal interest in the Society's JOURNAL. He announced also that Edward S. Seeley had been appointed National Chairman of the Papers Committee and that he would be assisted during 1951 by five regional Vice-Chairmen and one Vice-Chairman representing a specialized industry group (see Convention story above).

Charles W. Handley had been reappointed Chairman of the Progress Committee and Edmund A. Bertram had accepted the Chairmanship of the Historical and Museum Committee. Mr. Keith observed that the budget limitations during the last three months of 1950 had forced a slight reduction in the amount of material published in the JOURNAL. Changes which he, Mr. Frayne and Victor Allen had agreed on for JOURNAL format would improve appearance of the JOURNAL and it was noted that some budget relief might be achieved. Two other changes were the addition of abstracts of technical articles published elsewhere but not generally available to members, and the preparation of semitechnical reports of local Section meetings which were of serious interest to Society members but for which no formal manuscript had been prepared by the speaker. It was suggested that members in the three local Sections might be persuaded to prepare such reports regularly.

RECORDING DISCUSSIONS

Over the years, many attempts were made to record the discussions which follow presentation of technical papers at Society Conventions. Stenotype operators had been employed, as well as recording methods which used embossed tape, discs and quarter-inch magnetic tape. During the convention in Lake Placid last year, a professional model of magnetic recording machine was loaned to the Society and proved to yield the best results achieved so far. Mr. Keith suggested that a similar method, somewhat simplified, might well be adopted as a permanent system for recording, since the yield was higher and the cost somewhat lower than when using a stenotype operator. The Board accepted this suggestion and authorized Mr. Keith to proceed with the design and acquisition of suitable equipment which would be owned by the Society and maintained by the Headquarters Staff.

Another project that had been under Mr. Keith's supervision was the design of a more symbolic emblem for the Society to replace the one currently used on Society letterhead. Mr. Keith resigned as Chairman of that committee and Mr. Mole was asked to discuss the further activity along those lines with Lorin D. Grignon.

CONVENTIONS

In reviewing the 67th and 68th Conventions held in Chicago and Lake Placid during 1950, Mr. Kunzmann reported with some enthusiasm that income from registrations had offset convention expenses and he was able to turn in a black figure at the end of the year. He also reported on arrangements for the 69th Convention, in New York, as well as the 70th Convention, scheduled for the Hollywood-Roosevelt Hotel, October 15–19, 1951.

PLANNING FOR 1951

With reports of Society activity for 1950 completed, the Board considered the proposed budget for 1951 and endorsed a program of expansion, which included current growth in every phase of the Society's work. Space limitations at Society Headquarters have hampered engineering and publications activities to an extent that began to assume serious proportions. In recognizing this problem, the Board authorized the Executive Secretary to acquire larger quarters and to employ two additional staff members. One will pro-

vide additional stenographic assistance and the other will be a young engineer, assigned almost entirely to the Society's Test Film Program. His interests would be along the lines of quality control, test film production and the more accurate specification of particular films, either now being made or proposed for the future.

Expansion of publications activity by 72% was authorized and it was pointed out that the change in JOURNAL format would allow the editor to purchase the same amount of printed information for each dollar during 1951 as he did during the early months of 1950, even though general publications costs had increased considerably. Demand for additional technical work by Headquarters and by many of the committees seemed completely justified and an increase of the services thus provided by as much as 100% was authorized.

Membership procedures have been simplified so that a fairly large increase in the rolls could be handled by Headquarters with very little additional effort. This increased efficiency makes it practical for the Society to invite membership from many potential applicants who have not been aware of the services available. Headquarters has been requested to apply additional effort along these lines, with the hope that every potential candidate for membership will learn of the Society and its JOURNAL and as a consequence will be able to judge whether the benefits warrant his joining.

1951 Nominations

'VOTING' members of the Society, that is all those in the Active, Fellow and Honorary grades, are invited by the Chairman of the Nominating Committee to suggest candidates for the seven Board of Governors' vacancies which will occur at the end of 1951. Since the Nominating Committee for this year will soon begin its formal deliberations, names of potential nominees should be placed in the hands of the Chairman, Earl I. Sponable, c/o Movietonews Inc., 460 W. 54 St., New York 19, without delay.

Vacancies will be for the offices held now by the following members of the Board of Governors. The only limitations on suggested candidates for these vacancies are that they be *Voting* members of the Society.

Financial Vice-President, Ralph B. Austrian

Treasurer, Frank E. Cahill, Jr.

Governors, Lorin D. Grignon, Paul J. Larsen, William H. Rivers, Edward S. Seeley and R. T. Van Niman

Engineering Activities

Magnetic Recording

In the September, 1950, JOURNAL, it was reported that the proposals for Magnetic Sound Track on Film, originating in Glenn Dimmick's Subcommittee, were meeting obstacles in the parent Sound Committee. Those obstacles have been overcome and the proposals are now before the members of the Standards Committee, who are now balloting on their recommendation for preliminary publication for trial and comment.

Laboratory Practices

The Laboratory Practice Committee, under the Chairmanship of John Stott, met in January and pushed ahead on its ambitious program.

The work on 35-mm negative notching is reaching a conclusion and the committee will soon be canvassed on approval of the draft specification for size and location of notches.

16-Mm negative notching has presented a more thorny problem which will require

industry-wide assistance for solution. To this end, an interim committee report is being prepared for publication, with the expectation that sufficient comments will thus be elicited to enable the writing of an adequate draft specification.

A report of the Screen Brightness Survey of the 16-mm review rooms of the film processing laboratories was submitted. On the basis of the data accumulated at both East and West Coast laboratories, it was recommended that a 16-mm screen brightness standard be drafted, and concrete proposals to that effect are in the making.

The committee has been planning for some time to provide abstracts of chemical engineering material for a regular page in the JOURNAL. Proposals to achieve this were discussed and responsibilities fixed. We can, therefore, expect this valuable service to be initiated shortly.

Obituaries

Joseph Mina Bing, who was an influential force in amateur photography and in the photographic industry, died at his home in New York on December 9, 1950. He was 72 years old. He was born in Vienna and was graduated from the University of Vienna with the degree of Doctor of Engineering. He was engaged in consulting railroad work in Austria, South and Central American Countries and in the building of the Hell Gate Bridge.

In 1925 he became the first importer of photographic exposure meters, in which field he was an expert and designer. He later became one of the largest importers of cameras and other equipment. During World War II his manufacturing organization received two Army-Navy awards for its excellent work in producing Navy testing equipment and design of the underwater camera. Mr. Bing was an Honorary Fellow of both the Royal Photographic Society and the Photographic Society of America. He had been an Active Member of this Society for 22 years.

Lewis M. Townsend died on October 16, 1950. He had long been an active member in the Society. In 1925 he coauthored with L. A. Jones a paper "The Use of Color for the Embellishment of the Motion Picture Program," which was published in the TRANSACTIONS of the Society. He was also coauthor of many other papers. For several years he was Chief Projection Engineer of the Eastman Theatre and the School of Music at the University of Rochester. He was Technical Adviser on Sound Equipment for Paramount Publix from 1929 to 1932 and from 1932 until his death he was Chief Projectionist and Head of Equipment Maintenance for Schine Theaters, Inc.

Jack E. Beach was killed in a plane that crashed on Mt. Moran, Wyoming, November 21. He was 23 years old. He had worked as an assistant cameraman for Coronet Studios and as cameraman for C. O. Baptista Films, before being appointed to the staff of the New Tribes Mission as Production Manager in charge of their film work, which was to have been an exposition of missionary activities in the South. It was a mission-owned plane, destined for Florida, Bolivia and Brazil, on which he was killed.

Joseph W. Fleming, Manager of the Technical Information Center for Philips Laboratories, Irvington-on-Hudson, N.Y., was killed in an automobile accident on February 12, near his home in Edgewater, N.J. He had been an IATSE Member and had his own radio and sound business from 1929 to 1942 when he became associated with National Broadcasting Co. as Sound and Maintenance Engineer. Well known in radio and television, Mr. Fleming had served overseas in World War II as technical adviser to the U.S. Air Force in Europe and the Royal Air Force. At that time, he was also attached to the British Ministry of Aircraft Production. He had been an Active Member of this Society since 1947. He was also a member of the Audio Engineering Society, Institute of Radio Engineers and Photographic Society of America.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Babb, Harry L., Salesman, Eastman Kodak Co. **Mail:** 710 Crenshaw Blvd., Los Angeles 5, Calif. (A)

Barton, Cecil W., Electrical Technician, Universal Pictures Corp. **Mail:** 13924 Weddington St., Van Nuys, Calif. (M)

Bernd, Lester E., 16-Mm Motion Picture Producer, Delaware Steeplechase & Race Association. **Mail:** 11 Comeau St., Wellesley Hills 82, Mass. (M)

Bieling, Robert O., Head, Film Quality Control, Bell & Howell Co. **Mail:** 96 Commonwealth Rd., Rochester 18, N.Y. (M)

Blaskiewicz, John V., New Institute for Film and Television. **Mail:** 625 Hinsdale St., Brooklyn 7, N.Y. (S)

Braaten, Norman J., Audio-Visual Electronics Technician, Minneapolis Board of Education. **Mail:** 5152 29 Ave., S., Minneapolis 17, Minn. (A)

Brueckner, Hubert U., Superintendent, Optical Shop, Revere Camera Co. **Mail:** 1117 S. East Ave., Oak Park, Ill. (M)

Cambi, Enzo, Consulting Engineer, Cinecittà Studios; Lecturer, National Research Council (Italy) and Leghorn Naval Academy. **Mail:** Via Giovanni Antonelli 3, Rome, Italy. (A)

Cheda, Paul M., Artist. **Mail:** 90–47 53 Ave., Elmhurst, L.I., N.Y. (A)

Chen, Aegem, University of Southern California. **Mail:** 2610½ N. Broadway, Los Angeles 31, Calif. (S)

Cole, Henry James, Photographer, National Institutes of Health, U.S. Public Health Service. **Mail:** 212 Piping Rock Dr., R.F.D. #2, Silver Spring, Md. (M)

Day, James A., Projection Supervisor, WXYZ-TV, Inc. **Mail:** 12768 Elgin Ave., Huntington Woods, Mich. (A)

Duncan, Cyril J., Director, Dept. of Photography, University of Durham, King's College, Newcastle Upon Tyne, 1, England. (M)

Franzen, Russell G., Industrial Photographer, American Can Co. **Mail:** 1412 S. Fourth Ave., Maywood, Ill. (M)

Fussel, Alex, Theater Projectionist, Valuskis Theatres. **Mail:** 11914 Cheshire St., Norwalk, Calif. (A)

Gibbons, Thomas J., Jr., Sales Engineer, Minnesota Mining & Manufacturing Co. **Mail:** 909 Kingsley Dr., Arcadia, Calif. (M)

Gordon, James B., Director of Photography and Head of Optical Printing Dept., 20th Century-Fox Film Corp. **Mail:** 2225 Linnington Ave., Los Angeles 64, Calif. (M)

Graff, Lee, Chief Engineer, Brenkert Light Projection Co. **Mail:** 4510 Lawre Rd., Centerline, Mich. (M)

Heimbach, Newton, Chemist, Assistant Film Plant Manager, Bell & Howell Co. **Mail:** 145 Commonwealth Rd., Rochester, N.Y. (M)

Hoff, J. Robert, Sales Manager, The Ballantyne Co. **Mail:** 1707 Davenport St., Omaha, Nebr. (M)

Howard, Bruce, Audio Facilities Engineering & Recording Supervisor, Radio Station WBAP, (AM-FM-TV). **Mail:** 2754-B Primrose, Fort Worth, Tex. (M)

Huntsman, Harold F., Television Engineering Field Supervisor, KECA-TV. **Mail:** 409 Irving Ave., Glendale 1, Calif. (M)

Hyll, Richard, Laboratory Technician, Film Associates. **Mail:** 325 N. Main St., Bowling Green, Ohio. (A)

Iwerks, Donald, Assembly Dept., Photographic Products. **Mail:** 15153½ Dickens St., Sherman Oaks, Calif. (A)

Jayne, Stuart T., Assistant Plant Engineer, Pathé Industries, Inc. **Mail:** 1259 N. Mansfield, Hollywood 38, Calif. (A)

Johnson, Elisha H., School of Public Relations, Boston University. **Mail:** 177 Academy St., Jersey City 6, N.J. (S)

Johnson, Stanley L., University of Southern California. **Mail:** 1041 Browning Blvd., Los Angeles 37, Calif. (S)

Kotis, Arnold F. T., Free-Lance Camerman. **Mail:** 39–37—49 St., Long Island City 4, N.Y. (A)

Krause, Edward B., Manufacturer of Film Processing Equipment. **Mail:** 40 Birch Pl., Stratford, Conn. (M)

Lawrence, Robert L., Eastern Manager, Jerry Fairbanks, Inc. **Mail:** 235 E. 73 St., New York 21, N.Y. (M)

Mabuchi, Osamu, Electronic Engineer, Chemist, Matsushita Electric Industrial Co., Ltd. **Mail:** 38 Shimamachi, Nishikujo Shimosyo-ku, Kyoto City, Japan. (A)

Milwitt, William, Engineer, RCA Laboratories. **Mail:** 620 S. Catalina St., Los Angeles 5, Calif. (A)

Mueller, Gustave M., Supervisor, Machine Shop, Pathé Laboratories, Inc. **Mail:** 2913 Marsh St., Los Angeles 39, Calif. (A)

Nebbia, Michael, Free-Lance Cinematographer. **Mail:** 831 Lexington Ave., New York 21, N.Y. (A)

Oertel, John T., Motion Picture Laboratory Technician, George W. Colburn Laboratory. **Mail:** 701 Willow St., Chicago 14, Ill. (A)

Parker, Jackson G., Motion Picture Dept., University of California at Los Angeles. **Mail:** 476 Midvale, Los Angeles 24, Calif. (S)

Plass, Joseph P., Photographer, National Institutes of Health, U.S. Public Health Service. **Mail:** 4701 MacArthur Blvd., N.W., Washington, D.C. (M)

Racies, Larry, Camerman, Newsreel Service. **Mail:** 140 E. 46 St., New York 17, N.Y. (M)

Richards, Balfour A., District Engineer, Palace Amusement Co., (1921) Ltd., P.O. Box 211, Kingston, Jamaica, British West Indies. (A)

Riddle, William R., Television Film Editor, WOR-TV. **Mail:** 91 Central Park West, New York 23, N.Y. (A)

Roberts, Paul M., New York University. **Mail:** 29 Wadsworth Ave., New York 33, N.Y. (S)

Romans, William E., American Television Inst. **Mail:** 4030 N. Sheridan Rd., Chicago 13, Ill. (S)

Schwarz, George, Plant Manager, Rochester Film Div., Bell & Howell Co. **Mail:** 90 Browncroft Blvd., Rochester 9, N.Y. (M)

Scott, David C., Producer. **Mail:** 636 Las Casas Ave., Pacific Palisades, Calif. (A)

Seaman, Gerald, Hollywood University. **Mail:** 1411½ N. Alexandria, Hollywood 27, Calif. (S)

Shea, Robert P., Mechanical Engineer, Producers Service Co. **Mail:** 5447 Radford Ave., North Hollywood, Calif. (M)

Sheldon, John L., Research Physicist, Corning Glass Works. **Mail:** 112 E. Third, Corning, N.Y. (M)

Sinnett, Robert J., Chief Engineer, WHBF, AM/FM/TV, Rock Island Broadcasting Co. **Mail:** 3201 Twenty-Fifth St., Rock Island, Ill. (M)

Spielvogel, Bert, Motion Picture Cameraman, City of New York, WNYC-TV. **Mail:** 30 W. 105 St., New York 25, N.Y. (A)

Swedlund, Lloyd E., Electrical Engineer, Radio Corporation of America, RCA Victor Division, Lancaster, Pa. (A)

Tchakmaknian, Krikor, Sound Engineer, Nahas Studios, Pyramids Rd., Cairo, Egypt. (M)

Thomas, Philip F., Test Engineer, Western Electric Co. **Mail:** 5400 Columbus Ave., Van Nuys, Calif. (A)

Valentine, Christian, Jr., Art Director, Biow Co. **Mail:** 36–40 Bowne St., Flushing, N.Y. (A)

Van der Wyk, Jack, University of Southern California. **Mail:** 2739 Morningside St., Pasadena 8, Calif. (S)

Volmar, Victor, Publicity Director & Supervisor of Foreign Versions, Monogram International Corp. **Mail:** 55 Payson Ave., New York 34, N.Y. (A)

Wade, Roger W., Photographer, Motion Picture Producer, Roger Wade Productions. **Mail:** 77–17 247 St., Bellerose, N.Y. (M)

Weiss, Harry Allan, Sound Technician, Ryder 16-Mm Services. **Mail:** 6126 Orange St., Los Angeles 48, Calif. (A)

White, Lyman R., University of Southern California. **Mail:** 1066 W. 34 St., Los Angeles 7, Calif. (S)

CHANGES IN GRADE

Calhoun, John M., Chemist, Dept. of Manufacturing Experiments, Kodak Park, Eastman Kodak Co., Rochester, N.Y. (M) to (A)

Jamgochian, Matthew, Teacher, Los Angeles City Schools. **Mail:** 318 Road's End, Glendale 5, Calif. (S) to (A)

Law, Edgar, Chief Re-Recording Engineer, British Lion Studio Co., London Films Studio, Shepperton, Middlesex, England. **Mail:** 19 Delta Rd., Worcester Park, Surrey, England. (M) to (A)

Shapiro, Melvin, Editor, Projectionist, Production Assistant, Ryder 16-Mm Services. **Mail:** 823 N. Genesee, Los Angeles 46, Calif. (S) to (A)

Somes, George W., Sound Recording Technician, U.S. Navy Electronics Laboratory. **Mail:** 1247 Savoy St., San Diego 7, Calif. (A) to (M)

Willis, John B., Free-Lance Cameraman. **Mail:** Box 1567, Grand Coulee, Wash. (S) to (A)

DECEASED

Brake, Alan R., 143 S. Robertson Blvd., Los Angeles 3, Calif. (A)

Paolillo, Vincent, Field Engineer, Capitol Motion Picture Supply Corp., 630 Ninth Ave., New York (A)

BOOK REVIEWS

The Great Audience

By Gilbert Seldes. Published (1950) by Viking Press, 18 E. 48 St., New York 17. 229 pp. 5½ × 8½ in. Price $3.75.

Twenty-five years ago Gilbert Seldes in *The Seven Lively Arts* presented the then daring proposition that the popular arts—movies, radio, comic strips, vaudeville, etc.—should be assessed by the same critical standards which apply to the fine arts. He contended that the influence of such widely popular artists as Chaplin, Gershwin or Herriman merited serious esthetic consideration. Now, in his latest work, *The Great Audience*, he has reassessed the position of the mass arts and resituated them in a larger social frame of reference, feeling that, while their relation to the fine arts is now secure, the dominant mass entertainments—radio, movies and television—have taken on an additional significance as media of mass communication.

To his task Mr. Seldes brings an unusual combination of qualifications—a lively and sympathetic affection for the popular arts, bolstered by wide practical experience in television, radio and the movies, together with an incisive critical temper unencumbered by political or intellectual prejudices. Out of the tremendous upheaval and chaos resulting from the relocations now taking place in the entertainment field he has not only grasped and clearly analyzed the significant organizational and distribution problems, but has also offered reasonable proposals for reorganization of our existing political and economic framework.

He recognizes that the popular arts have certain characteristics which set them off from the fine arts, notably the fact that they are not made for the ages, but created to be quickly enjoyed and forgotten.

In his analyses of present-day conditions in the movie industry, Seldes proposes reorganization of the industry to meet the threats of television and diminishing box office receipts. He upsets many widely touted beliefs of the movie industry, such as "Nearly everyone goes to the movies," "the movie industry is the fourth largest in the U.S.," and that most of the profits of the industry come from production and releasing of movies. He points out that the manufacture of motion pictures actually ranks about forty-sixth, that the great bulk of movie profits comes from distribution and exhibition rather than from manufacturing, and that public opinion polls made for the industry have indicated many startling facts as to who actually goes to the movies today. The great majority of those who go to the movies today are under twenty years of age. After twenty-five, people gradually stop going to movies geared to adolescent tastes. Between thirty and forty, more than half the population of the U.S. does not go to the movies more than once a month, while after fifty half the population never goes at all. Thus the claimed eighty million paid attendances a week actually represent between thirteen and fifteen million individuals.

Movie manufacturers, faced by the loss of overseas markets, the inroads on a joint audience by television, and the enforced separation of manufacturing and exhibition facilities under antitrust regulations, find themselves in a precarious position. Part of the trouble lies in the standardized movie product itself, which Seldes claims has degenerated from the telling of a story to being the embodiment of a popular mythology gauged for the taste of the perennially adolescent movie audience, itself predicated on a fixed rate of birth and age turnover. Seldes proposes that the movies try to recapture their lost audiences by production of more varied and mature films and by increasing secondary channels of distribution for them along the lines of the "art" (or "sure seater") theater and the now vanished newsreel theater circuits. The financial success of "Hamlet" has proved that even a serious "class" film can, with proper exploitation and distribution, provide adult movie fare and at the same time make money.

In the competition of movies and television for the same mass audience, Seldes presumes three courses of action: (1) *a merger of interests* whereby the movie producers could make special films for television and movies for their own theaters, and use the latter for showing both films

and television features, (2) *compromise*—Hollywood may become a special manufacturing unit for television, at the same time making films for more mature and specialized movie audiences, (3) *active competition*—the movie industry might concentrate on action films, westerns and Technicolor musical extravaganzas where television cannot successfully compete.

Seldes believes television can be most effective in straight dramatic productions, where the artificial is immediately obvious and out of place, as well as in its presentation of sports and vaudeville. By combining live news events and newsreel film a unique documentary form might be developed. In an effective reorientation of the popular arts, television may capture the mass audience by presenting sports and vaudeville, radio may survive by presenting documentary, cultural and musical features, and movies by concentrating on the production of fiction and extravaganzas.

Provocative, thoughtful and well documented, *The Great Audience* is surely one of the most intelligent and searching examinations of the popular arts to appear in many years, significant for the industrial specialist and the general reader alike. To Seldes, the popular arts are of enormous significance in the culture of a democracy, and their development and control should be the concern of every citizen, since we are all in some degree affected by them whether we are aware of it or not.—THOMAS BARRY HUNT, 752 Greenwich St., New York 14.

Movies for TV

By John H. Battison. Published (1950) by Macmillan, 60 Fifth Ave., New York. 376 pp. + numerous illus. 5¾ × 8½ in. Price $4.25.

The recent growth of television has provided employment for many new people who find themselves in an unfamiliar world. Also, many old hands in advertising and the theater feel the lack of basic information on a new art and science. It is to these people that this book is directed.

To quote the jacket, "This book . . . provides information both on technical equipment and on program planning, needed to insure the best results from movies on television, including a great deal of experienced advice on technical and artistic details which may cause trouble."

On page 128 the author says, "But the reader of this book will not normally be expected to have much to do with the technical side." And on page 246, "This book is not intended to produce engineers, producers, or even technicians, but after reading and studying it the reader should be well prepared for any job in the film department of a television station that does not require specialized technical knowledge. It should be equally helpful to anyone else who is concerned with films for television."

Obviously any single book which treats such a wide variety of subjects must touch upon each rather lightly. But for the person who wishes to gain a quick broad view of these subjects, Mr. Battison presents it with an easily read seminarrative style that is clear and pleasing.—C. L. TOWNSEND, National Broadcasting Co., 30 Rockefeller Plaza, New York.

Preparation and Use of Audio-Visual Aids

By Kenneth B. Haas and Harry Q. Packer. Published (1950) by Prentice-Hall, Inc., 70 Fifth Ave., New York 11. i–xii + 327 pp. including 36 pp. appendix and 7 pp. index. Profusely illus. 6 × 9 in. Price $4.65.

This is the second edition of a well-known textbook. The first edition was "aimed at industrial and store personnel trainers." In this revision the authors attempted to broaden its appeal and usefulness, but much of the original plans remains.

The authors have compressed into a relatively few pages an enormous amount of information about every type of audio-visual aid. The book contains many lists of criteria for materials and rules on utilization of them. Although the authors keep the viewpoint intensely topical and devote very little space to theoretical considerations such as the psychology behind the use of audio-visual materials, the book is so complete that it constitutes a reference work in the field. All of the well-known instructional aids and some of the less well known are included. Two of the best

chapters are on using the blackboard and on setting up and operating an audio-visual laboratory. The chapter on the laboratory will be especially useful to schools of education. The authors have made good use of line drawings to enliven the text. Since the illustrations are so good it is surprising to find no examples of charts, such as pie charts and bar graphs.

The book is so full of ideas and hundreds of practical suggestions that the compression necessary to get these into a small space has resulted in some subjects being slighted. It is impossible, obviously, to explain photography in two or three pages or outline objective research methods in one page. This book, therefore, is not a thorough discussion of any one phase of audio-visual education but is an overview of the whole subject. There is an appendix on sources of materials and equipment.—PAUL R. WENDT, College of Education, University of Minnesota, Minneapolis 14.

Current Literature

THE EDITORS present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 31, no. 10, Oct. 1950

Choosing a 16Mm Camera for Professional Work (p. 342) L. ALLEN

New Technicolor System Announced (p. 354)

vol. 31, no. 11, Nov. 1950

Economy Prime Factor in Producing Films for TV (p. 377) H. A. LIGHTMAN

Advantages of Variable Shutters in 16Mm Cine Photography (p. 386) J. FORBES

vol. 31, no. 12, Dec. 1950

New Technicolor System Tested by Directors of Photography (p. 414) L. ALLEN

Surgical Cinematography (p. 417) F. C. ELLS

New Camera and Tripod Carrier Developed at MGM (p. 418) F. FOSTER

British Kinematography

vol. 16, no. 4, Apr. 1950

Technical Requirements of a Mobile Studio Unit for Feature Films (p. 109) B. HONRI

Modern Kinema Equipment: III., Accessory Equipment and Film Mutilation (p. 122) R. A. RIGBY

Improvements in Large-Screen Television (p. 126) T. M. C. LANCE

vol. 16, no. 5, May 1950

Maintenance of 16Mm Print Quality

I. The Renter's Problems (p. 152) E. F. BRADLEY

II. Problems in the Field (p. 154) M. RAYMOND, JR.

vol. 16, no. 6, June 1950

High-Diffusion Screens for Process Projection (p. 189) H. McG. ROSS

vol. 17, no. 2, Aug. 1950

Science and the Motion Picture (p. 42) R. WATSON-WATT

The Evolution of the Newsreel

I. Introduction (p. 47) H. THOMAS

II. The Early Days of Newsreels (p. 47) K. GORDON

III. The Development of the Sound Newsreel (p. 50) W. S. BLAND

IV. The Future of the Newsreel (p. 53) H. THOMAS

History and Development of the Colour Film (p. 57) R. H. CRICKS

vol. 17, no. 3, Sept. 1950

Electrical Devices as Applied to Special Effects

I. Problems of Remote Control (p. 84) J. GOW

II. Miscellaneous Equipment (p. 85) F. GEORGE

Electronics

vol. 23, no. 8, Aug. 1950

Improved Deflection and Focus (p. 94) C. V. BOCCIARELLI

vol. 23, no. 12, Dec. 1950

Color Fundamentals for TV Engineers (p. 88) D. G. FINK

vol. 24, no. 1, Jan. 1951

Color Fundamentals for TV Engineers, Pt. II (p. 78) D. G. FINK

Illuminating Engineering

vol. 45, no. 10, Oct. 1950

Television Studio Illumination (p. 606) H. M. Gurin and R. L. Zahour

International Photographer

vol. 22, no. 11, Nov. 1950

Color of Illumination (p. 5) D. Norwood

More About "Inspacian" (p. 8) I. M. Terwilliger

vol. 22, no. 12, Dec. 1950

TV Newsreel Production Technique (p. 5) J. Sandstone

Smallest TV Camera (p. 8) A. L. Marble

International Projectionist

vol. 25, no. 7, July 1950

Notes on Modern Projector Design, Pt. III (p. 5) R. A. Mitchell

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"Videofilm" Theatre TV System Using 16Mm Stock in Production (p. 37)

All-Plastic Screen in Radio City Music Hall (p. 38)

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Servicing the 16Mm Sound Projector (p. 36) D. D. Emerson

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The FCC Color TV Decision (p. 26)

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Video Recordings Improved by the Use of Continuously Moving Film (p. 32) W. D. Kemp

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Approaches to Color TV (p. 44) J. H. Battison

High Definition Monochrome TV (p. 52) F. Loomis

A New Video Distribution System (p. 28) E. D. Hilburn

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Subtractive Color TV (p. 12) I. Kamen

Video Special-Effects System (p. 14) E. M. Gore

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Metal-Backed TV Picture Tubes (p. 12) C. T. Waugh

Society Awards for 1951

There are now six formal Society Awards which are available for presentation annually to industry engineers who meet the qualifications briefly stated here.

Detailed reports of qualifications of all previous recipients of three of the awards are presented on pp. 641–643 of the Journal for May, 1950, and illustrations showing both sides of two of the Society's medals appear on pp. 476–477 of the April, 1949, Journal. Suggestions for possible candidates to be considered by the several award committees may be sent to Society Headquarters or addressed directly to the individual chairmen.

FELLOW AWARD

Members in the Active grade who by their ". . . proficiency and contributions have attained outstanding rank among engineers or executives of the motion picture industry" may be proposed and considered as possible award nominees by the Fellow Award Committee. Such proposals will be received only from present Fellows of the Society and should be addressed to

Chairman, Earl I. Sponable, Fox Movietonews, Inc., 460 West 54th Street, New York 19, N. Y.

HONORARY

The Honorary Membership Award is a distinction given to pioneers who have contributed inventions of basic importance to the industry or whose contributions have made possible better production, administration or utilization of motion pictures. Recommendations for the Honorary Membership Award may be submitted by any member of the Society and must be endorsed by at least five Fellows, who are required to set forth in writing their knowledge of the accomplishments which appear to justify presentation of the Award. Such recommendations must be addressed to the Honorary Membership Committee Chairman, Gordon A. Chambers, Motion Picture Film Dept., Eastman Kodak Company, 343 State St., Rochester 4, N.Y.

JOURNAL AWARD

The Journal Award is presented annually at the Fall Convention of the Society to the author of the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year. Technical merit, originality and excellence of presentation are three major considerations. The authors of papers of nearly equivalent merit often receive Honorable Mention. The Journal Award Committee, appointed by the President is now under the Chairmanship of Mr. Paul Arnold, who will shortly be receiving from members of his Committee, their recommendations for the most outstanding paper for 1950. His address is: Ansco Corp., Binghamton, N.Y.

SAMUEL L. WARNER MEMORIAL AWARD

Each year the President appoints a Samuel L. Warner Memorial Award Committee to consider candidates for the Award. Preference is given to inventions or developments occurring in the last five years, and also to inventions or developments likely to have the widest and most beneficial effect on the quality of reproduced sound and picture. The Award is made to an individual and may be based upon his contributions of the basic idea involved in the particular development being considered and also on his contributions toward the practical working out of the idea. The purpose of the Award is to encourage the development of new and improved methods or apparatus designed for sound on film motion pictures, including any step in the process. The present Chairman of the Committee is Glenn L. Dimmick, RCA Victor Division, Bldg. 10-4, Camden, N.J.

PROGRESS MEDAL AWARD

Written recommendations for candidates for the Progress Medal Award may be submitted by any member of the Society, giving in detail the accomplishments which appear to justify consideration. Qualifications should include invention, research, or development which has resulted in a significant advance in the development of motion picture technology and should be seconded in writing by any two Fellows or Active members of the Society, after which the recommendations must be filed with the Chairman of the Committee. For 1951, the Chairman is D. B. Joy, National Carbon Div., Union Carbide and Carbon Co., 30 E. 42 St., New York 17.

DAVID SARNOFF GOLD MEDAL

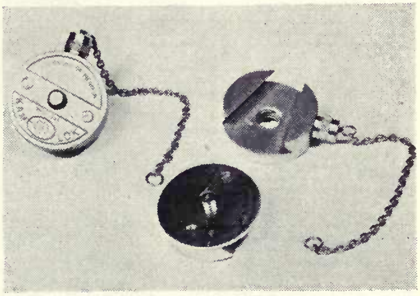
Most recent of the Society Awards is the David Sarnoff Gold Medal, offered by the Radio Corporation of America to a recipient to be selected by a committee appointed annually by the President of the Society. It will be presented annually at the Fall Convention to an individual "who has done outstanding work in some technical phase of the broad field of television or in any similar phase of theater television, whether in research, development, design, manufacture or operation."

The award will consist of a gold medal, a bronze replica and a certificate which states the accomplishments which justify its presentation. Its objective is "to encourage the development of new techniques, new methods and new equipment which hold promise for the continued improvement of television."

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

The Johnson Kam-Lok is designed to enable a camera to be quickly attached to or detached from a tripod. The two parts which fit together are released by pulling the chain attached to the spring-loaded locking pin. The top portion is screwed into the tripod bush of the camera and can be left there. The lower part is screwed onto the tripod. It is suited to small movie cameras as well as still cameras. The Johnson Kam-Lok is distributed by General Photographic Supply Co., 136 Charles St., Boston 14, Mass.



An Underwater exposure meter has been developed by Fenjohn Underwater Photo & Equipment Co., 90 Cricket Ave., Ardmore, Pa. A Weston Model 852 exposure meter has been enclosed in a watertight, light-weight, cast-aluminum case. Designed for use in subsurface photography and in tropical atmosphere, it weighs in air 16 oz and is 3 × 4 × 1½ in. It is priced at $168.00 including Federal tax.

A Control Track Generator, for synchronous recording with a tape recorder already in use, has been designed by, and is available from, Fairchild Recording Equipment Corp., 154 St. and 7th Ave., Whitestone, N.Y. Called Fairchild Unit 140, the cost is $335.00 f.o.b. Whitestone. It will extend the functions of the tape recorders which are performing within the specifications published as the NAB Primary Standard, so that such recorders may meet operational requirements of the film and television industries. The control track signal is mixed with the program signal so that both are simultaneously recorded. When played back on the manufacturer's Pic-Sync reproducer, the recorded program is synchronous with the frequency of the power line which supplied the original recorder and is therefore in "sync" with any other equipment operating from the same line at the same time.

1950 Radiofile Annual is the fifth yearly annual now available from the publisher, Richard H. Dorf, 255 W. 84 St., New York 24. *Radiofile* is a bimonthly publication which indexes and cross-indexes by subject all articles of technical interest in 15 leading American radio and television magazines and journals, which includes the Journal. The sixth *Radiofile* for a year represents all items indexed for that year, for the index is cumulative. The 1950 *Radiofile Annual* is sold for $0.50, and a regular yearly subscription to *Radiofile* is $2.00.

SMPTE Officers and Committees: The Roster of Society Officers was published in the May 1950 Journal. For Administrative Committees see pp. 515–518 of the April 1950 Journal. The most recent roster of Engineering Committees appeared on pp. 337–340 of September 1950 Journal.

Bruno E. Stechbart

After 37 years of designing precise mechanisms for the motion picture industries, Bruno E. Stechbart resigned from active work with the Bell & Howell Co. He joined Bell & Howell in 1927 as Development Engineer, became Assistant Chief Engineer in 1929 and ten years later, when A. S. Howell, one of the Company's founders and its Technical Director from the beginning, retired, he became the Chief Engineer. He was elected Vice-President in Charge of Engineering in 1944 and held that position until July 18, 1950, his 60th birthday and the official date of his retirement.

His application for membership in the Society was dated August 8, 1921. At that time, he was Chief Engineer of the American Projecting Co. in Chicago. In 1929, the Society elevated him to the grade of Fellow.

Mr. Stechbart was born in Lode, Russia, (later Poland and Germany), on July 18, 1890. He came to the United States in 1906 and, having both interest and aptitude along mechanical lines, found regular work in machine shops. To round out his knowledge, he studied during off hours and at night. In 1913, he became so interested in a 35-mm combination camera-projector venture that he decided to cast his lot permanently with the camera apparatus end of the then-growing motion picture industry. After a period of experimentation, he developed a 35-mm projector, the Projectoscope, which was taken up by the American Projectoscope Co., a subsidiary of the American Film Company. He was then employed by them for a period of six years. In 1926, he joined the De Vry Corporation as Chief Engineer, leaving there a year later to become a Development Engineer at Bell & Howell.

Among his former associates, he is known for his engineering skill and meticulous attention to details of design. The products developed under his guidance present adequate corroboration as does the technical article "The Bell & Howell Fully Automatic Sound Picture Production Printer" that appeared in the Journal for October, 1932. He was coauthor with A. S. Howell and R. F. Mitchell. At the present time, he holds 46 patents and has several applications pending.

Now, in retirement, Mr. and Mrs. Stechbart have moved from Chicago to 206—49th Street West, R. D. No. 1, Bradenton, Fla.

Meetings of Other Societies

American Physical Society, Apr. 26–28, Washington, D.C.
Acoustical Society of America, May 10–12, Washington, D.C.
American Physical Society, June 14–16, Schenectady, N.Y.
American Physical Society, June 25–28, Vancouver, Canada
American Institute of Electrical Engineers, June 25–29, Toronto, Canada
Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

High-Temperature Film Processing

Its Effect on Quality

By Richard Hodgson and Jack Hammer

The processing of motion picture positive film by high-temperature developers and fixing solutions, and subsequent drying by turbulent air, results in film quality which is superior in some respects to film processed by conventional laboratory methods. Positive pictures, printed from an original camera negative, were processed by conventional techniques and by high-temperature methods.

Methods and techniques to reduce the time required for processing of motion picture film have been investigated for a great many years, but the problem has received accelerated attention in the last five years. The increased interest in the problem primarily comes from three fields: (1) television film recording, (2) military applications, and (3) theater television.

Paramount Pictures' interest has been primarily in the rapid processing of television film recordings and theater television. The first rapid processing system was developed by Paramount five years ago and it processed and dried film in approximately three minutes. Continued development effort has resulted in this time being reduced to 25 sec by using a high temperature (120 F) saturated solutions of caustic developers and fixers and turbulent air drying.

The development work on turbulent high-velocity air drying was done jointly by Paramount and Raytheon Manufacturing Co. The following paper in this Journal describes in detail this new technique. Currently theater television equipments which Paramount is constructing and selling include this new type drier. Figure 1 shows a typical installation of the Paramount system, including the turbulent air drier.

In shrinking the complete film processing time from the conventional commercial laboratory practice of approximately 40 min to 1% of that (25 sec), it was expected that to some degree the quality would suffer and that the print life would be short. This, however, has not been the experience with the millions of feet of film that has been processed in this manner by Paramount.

Presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by Richard Hodgson and Jack Hammer, Paramount Pictures Corp., Times Square, New York 18. For discussion, see the consolidated discussion following the next paper in this Journal.

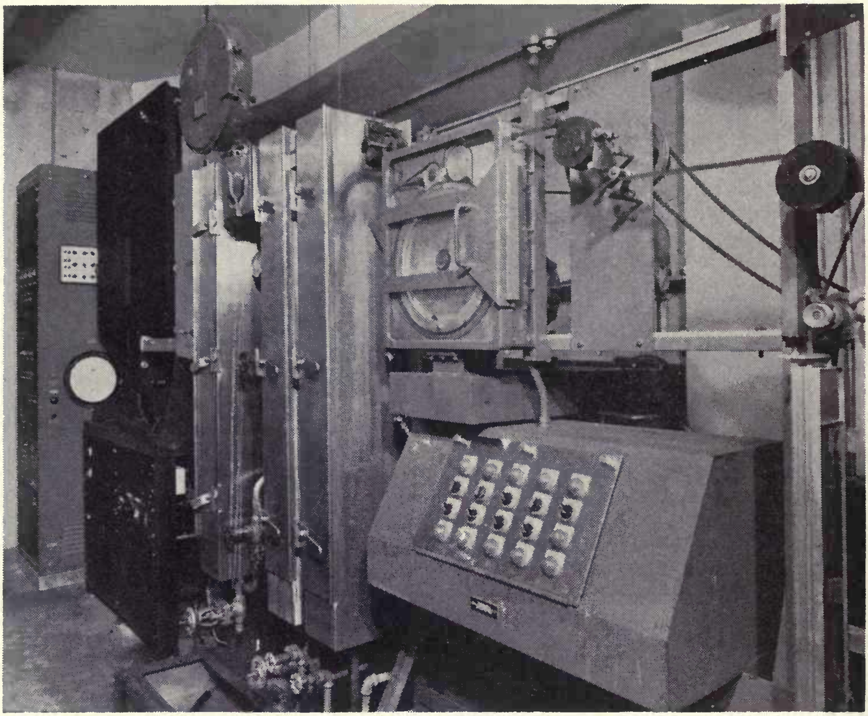


Fig. 1. The Paramount system, including turbulent air drier.

To demonstrate these results, two prints were made in an identical manner from an original camera negative of a "Sportlight" short. The same printer light setting was used in each case. One was processed by the conventional commercial laboratory procedure in 40 min with a $3\frac{1}{2}$-min carbonate developer at 68 F. The other print was processed and dried in Paramount's high-speed equipment in 25 sec. The gamma of both prints is the same.

(At the Convention, identical sections from each print were projected and the audience was asked to state which print had the higher quality. Approximately 85% of the members attending the session voted that the print processed in 25 sec had superior quality.)

Photomicrographs (445×) were made of identical portions of picture frames from both the 40-min (Fig. 2) and 25-sec (Fig. 3) prints. Close examination of these photomicrographs indicated that no detectable difference in grain size exists. The grain size is approximately 1.2 microns in each instance.

One general film processing technician is required to operate the equipment. Chemicals are packaged in formula proportions so that only simple water mixing is required. This type of equipment is now in commercial operation as part of the theater television installations in Detroit, Minneapolis, Toronto, Chicago and New York, and additional installations are underway.

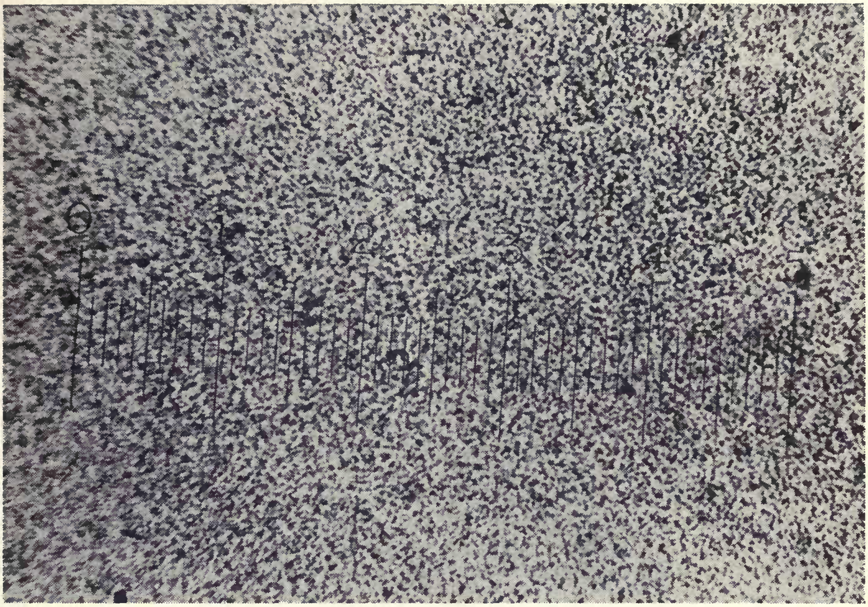


Fig. 2. Photomicrograph of film processed 40 min.

Fig. 3 Photomicrograph of film processed 25 sec.

Ultrarapid Drying of Motion Picture Film by Means of Turbulent Air

By Leonhard Katz

The problem of rapid processing of motion picture film has received considerable attention in the last decade. Although considerable study has been made of various methods to increase the speed of developing, fixing and washing, relatively little effort has been expended to improve the speed of drying. A description is herewith given of a number of different equipments which were designed after a theoretical investigation had been made of the drying problem. These equipments permit the ultrarapid drying of motion picture film in a convenient manner with extremely low distortion. One application of these units has been incorporated in the Paramount Theater-Television Units for the rapid processing of 35-mm film.

Basic Theory of Mass Transfer

Motion picture film can be considered as consisting of a base which absorbs practically no water and a gelatin layer which absorbs a very large amount of water. The drying of motion picture film requires that the water molecules diffuse out of the gelatin layer to the surface where they can be carried off by the surrounding medium. The rate of evaporation will be completely controlled by the rate of mass transfer of the water through the gelatin and through the surface layer between the gelatin and the surrounding medium.

In order to study this problem more closely it is well to consider the general theory of mass transfer between a solid substance (containing a liquid agent) and a gaseous surrounding, as shown in Fig. 1. From this general theory it will then become apparent which parameters can be varied to obtain the maximum rate of mass transfer and so obtain a maximum speed of drying.

It has long been recognized that in a heat and mass transfer problem the heat and mass transfer will depend on a number of variables as follows:

1. The area of contact over which heat or mass transfer takes place.
2. The driving force, i.e., the temperature difference in case of heat transfer, or pressure difference in case of mass transfer.
3. The resistance to mass or heat transfer which is proportional to the thickness of the stagnant layer existing at the dividing surface between the two media.

The first two variables have usually been well recognized and it is the usual practice to increase heat or mass transfer by increasing the surface area or

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Presented on October 17, 1950 at the Society's Convention at Lake Placid, N.Y., by Leonhard Katz, Raytheon Manufacturing Co., Waltham 54, Mass.

Symbols, Definitions, Dimensions and Values

A = area normal to heat or mass transfer, sq ft
B = thickness of stagnant layer, ft
C_p = specific heat = 0.240 Btu/lb. °F = 0.514 w/cfm − °C for air at 100 F
D = equivalent diameter, $D = 4s/p$, ft
E_a = rate of mass transfer, lb/hr $E = 3.18 \times 10^{-4} \times Jm$, for water evaporation
f = dimensionless fluid flow friction factor; $f = 0.046/Re^{0.2}$
g = acceleration of gravity = 32.2 ft/sec² on earth
h = wall-to-fluid heat transfer coefficient, Btu/hr − sq ft − °F
J = film speed through drier, fpm
k = thermal conductivity = 1.56×10^{-2} Btu/hr − ft² − (°F/ft) for air at 100 F
L = length of film exposed to turbulent air
m = mass of water in film sample
M = molecular weight
n = number of ducts carrying air
p = perimeter of air-carrying duct
Pr = Prandtl number, dimensionless, defined as 3,600 $C_p\mu/k$
R = universal gas constant
R^* = gas constant per lb; for water vapor $R^* = 4.05 \times 10^{-2}$ ft³ − atm/°R − lb·H_2O
Re = Reynolds number, dimensionless, defined as $DV\rho/\mu = 4w/\mu p$
T = temperature. T_w = average over wheel; $R°$ = (460 + °F) = (492 + °C × 1.8)
U = air volume, cfm; U = nVs
V = air velocity, fpm
W = mass flow $W = 60\ U\rho$ lb/hr = $U\rho/60$ lb/sec
α = proportionality constant
δ = molecular diffusivity = 0.94 sq ft/hr for water vapor in air, at 100 F
μ = viscosity = 1.29×10^{-5} lb/ft-sec for air at 100 F
ρ = density = 7.1×10^{-2} lb/cu ft for air at one atm and 100 F
ϕ = partial pressure, atm; for water vapor in air, ϕ = 1.61 × (absolute humidity)
θ = time

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increasing the driving force, i.e., raising the temperature.

The third variable which takes into account the resistance to heat or mass transfer in the stagnant layer, has not always been fully recognized, and it will be shown here that a considerable improvement in rate can be obtained by reducing the thickness of the stagnant layer. This will be the case especially where the stagnant layer is the controlling factor as in the drying of motion picture film.

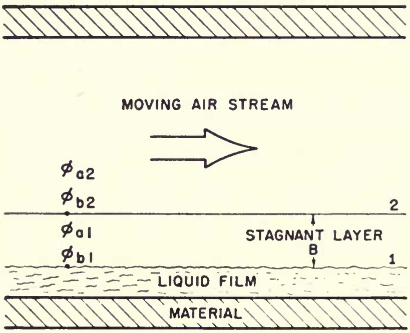

Fig. 1. Schematic drawing of the theory of mass transfer between a solid substance (containing a liquid agent) and a gaseous surrounding.

The stagnant layer can be considered as a relatively nonmoving layer of air which has the vapor pressure and temperature of the liquid on one side and the vapor pressure and temperature of the gas on the other side. It should be recognized, however, that the stagnant layer may not always be the controlling factor, so that care must be taken in applying this theory to other drying problems.

The drying process can be considered as a phenomenon normally included in the field of molecular diffusion. In

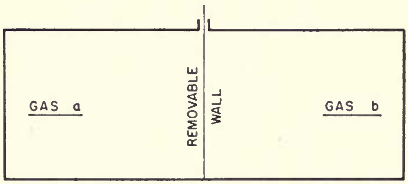

Fig. 2. Schematic drawing of the general theory of diffusion of gases.

order to get a better understanding of the problem, a short review of the theory of molecular diffusion is given here.

General Theory of Diffusion*

Let us consider two gases, *a* and *b*, as shown in Fig. 2, separated by a wall, at equal pressure and temperature. If the wall is removed, the gases will mix rapidly even though no external force is applied. It is apparent that an internal force of some sort is at work here, and the process by which the gases mix is called molecular diffusion. It has been assumed in elementary theoretical discussions that the molecules of the gases are extremely hard little balls, that their velocity has a Maxwellian distribution, and that the mean free path is very small. Maxwell assumed that the resistance to diffusion will be a function of the number of molecules in gases *a* and *b*, the difference in flow velocity, and proportional to the length of the diffusional path. The original equation as proposed by Maxwell was:

$$d\phi_a = \alpha_{ab} \frac{\rho_a}{M_a} \frac{\rho_b}{M_b} (V_a - V_b)\, dx \quad (1)$$

Under conditions of equal molal diffusion, and assuming that the Gibbs-Dalton law holds and that the gas is a perfect gas, it can be shown that:

$$\frac{E_a}{A\,M_a} = -\frac{RT}{\alpha(\phi_a + \phi_b)} \frac{d\phi_a}{dx} = -\frac{R^2T^2}{\alpha M_a (\phi_a + \phi_b)} \frac{d\rho_a}{dx} \quad (2)$$

* *Note:* Only the results of a rather lengthy mathematical treatment are given in this paper. For an exact derivation of the following equations the reader is referred to: (1) Lecture Notes, Course 2:43, Prof. J. Kaye, Massachusetts Institute of Technology; and (2) "Engineering Report on High-Speed Turbulent Air Film Dryer," (Private Doc.) Raytheon Manufacturing Co., January 19, 1950. The general theory of turbulence and its effects have been discussed in a large number of papers, most of which are listed in the Bibliography.

where R is the universal gas constant. The diffusivity

$$\delta = \frac{R^2T^2}{\alpha(\phi_a + \phi_b)} \quad (3)$$

is now a characteristic which can be compared to thermal conductivity in heat transfer equations.

The diffusion of two gases can be investigated by making the following assumptions:

1. Equal molal flux;
2. Gibbs-Dalton law holds;
3. Gas is a perfect gas;
4. Pressure is constant; and
5. Temperature is constant.

For the general case of equal molal diffusion of a gas, *a*, into a gas, *b*, and a gas, *b*, into a gas, *a*, the following equation can be written:

$$\frac{\partial\phi_a}{\partial\theta} = \frac{R^2T^2}{\alpha(\phi_a + \phi_b)} \frac{\partial^2 \phi_a}{\partial x^2} = \delta \frac{\partial^2\phi_a}{\partial x^2} \quad (4)$$

For the special case of the diffusion of a gas, *a*, through a stagnant layer of gas, *b*, we can assume that the flux of gas *b* is zero and the equation becomes as follows:

$$\frac{E_a}{A} = \frac{\delta(\phi_a \div \phi_b)}{R^*\ TB} \left[\frac{\phi_{a1} - \phi_{a2}}{\phi_{bm}}\right] \quad (5)$$

where R^* is the gas constant converted for mass of water vapor,

$$\text{where } \phi_{bm} = \left[\frac{\phi_{b2} - \phi_{b1}}{\ln(\phi_{b2}/\phi_{b1})}\right] \quad (6)$$

It should be noted that gas *b* remains stagnant because the molecules of gas *a* tend to carry gas *b* along in the direction of diffusion of *a*, but the resulting partial pressure gradient of *b* causes *b* to diffuse in the opposite direction. The two rates of travel of gas *b* are equal and opposite and thus cancel.

For the drying of solids it can initially be assumed that the surface of the solid is always wet and that the rate of drying is entirely governed by the rate of diffusion from the surface. This is true initially until a certain point has been

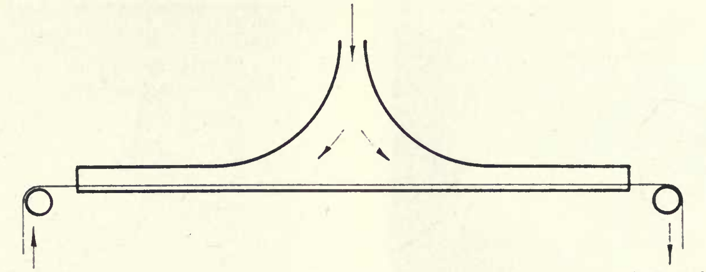

Fig. 3a. Experimental setup for film drier.

reached, whereafter the drying is determined by the rate of diffusion of liquid through the solid to the surface. The mass transfer when the surface is wet is governed by:

$$E_a = A \frac{\delta(\phi_a + \phi_b)}{R^* \, TB} \frac{(\phi_{a1} - \phi_{a2})}{\phi_{bm}} \quad (7)$$

For the rate of diffusion from a layer of liquid to gaseous surroundings, moving in turbulent flow, the following equation has been established experimentally by Gilliland.*

$$\frac{D}{B} = .023(Re)^{0.83}\,(Pr)^{0.44} \quad (8)$$

It can be seen from Eq. (7) and (8) that the fundamental parameter in mass transfer is the Reynolds number, a dimensionless quantity depending on the flow and physical properties of air, and on the geometry of the duct through which the air passes. We also note that this equation contains B, which is the effective stagnant air-layer thickness through which the water must diffuse. If we assume that the rate of evaporation is not limited by the diffusion of liquid through the solid, that is that the surface is always wet, an increase in the rate of evaporation can obviously be obtained by reducing the thickness of the stagnant layer, B. This, of course, can be done by choosing the parameters in Eq. (7) and (8) in such a fashion that the Reynolds number is very large and the diameter, D, is very small.

* Lecture Notes, Course 2:43, Prof. J. Kaye, Massachusetts Institute of Technology.

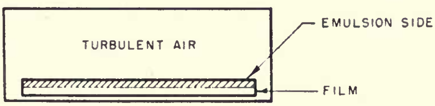

Fig. 3b. Cross section of tube for turbulent-air film drier.

The total rate of evaporation of the liquid through the stagnant layer is given as follows:

$$\frac{E}{A} = \frac{\delta\,(\phi_2 - \phi_1)}{560\;B\;R^*} \left[\frac{1}{1 - \phi_M}\right] \quad (9)$$

where ϕ_1, varying along the length of the drier, is the partial pressure of water in the air stream, ϕ_2 is at 100% relative humidity at the surface of the film, and ϕ_M is the logarithmic mean of ϕ_1 and ϕ_2. The final bracket in Eq. (9) is the effect of the stagnant air. This bracket can be dropped out as long as $\phi_M \ll 1$, as is the case in most of our applications, where a total pressure of 1 atm is maintained. 560 R is used as the temperature, T, since δ was found at 100 F and δ/T remains nearly constant in the operating range.

It can be seen that the amount of water evaporated will be a function of the diffusivity of the material, δ, the log mean partial pressure difference between the water and the air, and the thickness of the stagnant layer, B.

By proper mathematical manipula-

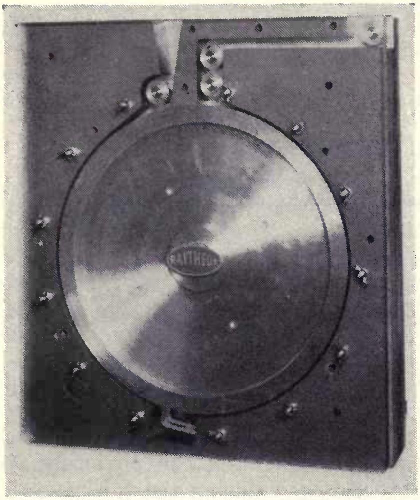

Fig. 4. Type K-3 turbulent-air high-speed film drier.

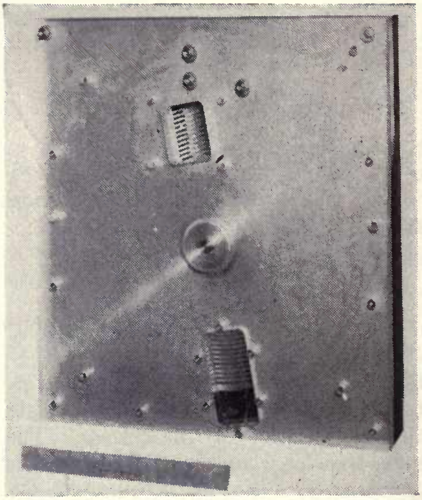

Fig. 5. Rear view of K-3 film drier showing turbulent-air heat exchanger

tion this can be reduced to the following simplified equation:

$$E = 2.65\,U(\phi_2 - \phi_{1A})\,[1 - e^{-6.88} \times 10^{-3}/BU] \quad (10)$$

We notice that this equation contains only those variables which are readily measurable, i.e., E, U, ϕ_2, and ϕ_{1A}. The quantity, B, which is still in this equation can be eliminated by combination with Eq. (8). By substitution and by the introduction of suitable parameters, a proper design can then be chosen for a high-speed film drier. For example, for the film drier shown in Fig. 4 substitution of the design parameters resulted in the following equation:

$$\frac{1}{B} = 82.6\, U^{0.8} \quad (11)$$

This equation relates the thickness of the stagnant layer to the amount of turbulent air blown over the film in cubic feet per minute. To determine the total amount of water evaporated, an equation can be derived from the combination of Eq. (10) and (11) which results in the following expression:

$$E = 2.65\,U(\phi_2 - \phi_{1A})[1 - e^{-0.568/U^{0.2}}] \quad (12)$$

This equation is the final relation which expresses the amount of water evaporated in a specific length of film as a function of the relative humidity and the amount of air blown over the film. A graphic representation of this equation is shown in Fig. 7 as the dotted curve which shows the expected amount of water removal as a result of the application of the foregoing theories.

This indicates that it should be possible to build extremely compact equipment capable of drying motion picture film at high speed and moderate temperatures (approximately 50 C). The dotted curve in Fig. 7 was computed for an air flow of 107.5 cfm. Different results can be obtained if the air flow is also changed and a whole series of curves have been obtained showing the relationship of air flow, temperature and water removed.

Construction of Equipment

If motion picture film is to be dried rapidly by application of the theories previously described, a unit must be designed which will permit turbulent air to be introduced over the wet film.

The first experimental unit was therefore constructed which consisted of a rectangular tube as shown in Fig. 3a, with a cross section as shown in Fig. 3b. Air at a pressure of 3 psi was introduced at the center of the tube at a rate of approximately 150 cfm. The film was pulled through the tube by a conventional sprocket drive. Experiments with this unit during the early part of 1949 indicated that even with this elementary unit 35-mm film could be dried at a rate of 75 fpm, but a number of difficulties were observed. The film was scratched by the bottom of the rectangular tube and considerable flutter existed. Also at this large rate of evaporation the film was cooled to near the freezing point of water and this cooling caused breakage due to reduced elasticity of the film. Heating the air relieved the situation somewhat but the body of the film remained still very cool.

In order to overcome these difficulties a second unit was built as shown in Figs. 4 and 5. This unit consists of a wheel 16 in. in diameter over which the film was led, with the back side of the film resting on a wheel. Air was introduced in the rear of the unit and was first passed through a turbulent air heat exchanger contained in the wheel (see Fig. 5). This maintained the wheel at a sufficiently high temperature to prevent excessive cooling of the film due to evaporation. After the air had passed through the heat exchanger it then was introduced over the film where it passed from the top around both sides of the wheel to the bottom. A small channel in the left-hand bottom side of the wheel was used to dry the back of the film by forcing air along it to blow off any moisture droplets still retained on the back side of the film.

This unit operated quite satisfactorily and a very large amount of film was dried on this equipment at a rate of 100 fpm. This unit was also demonstrated in conjunction with the Paramount Theater-Television Equipment at a show in September 1949 for the Theatre Owners of America in Hollywood, Calif.

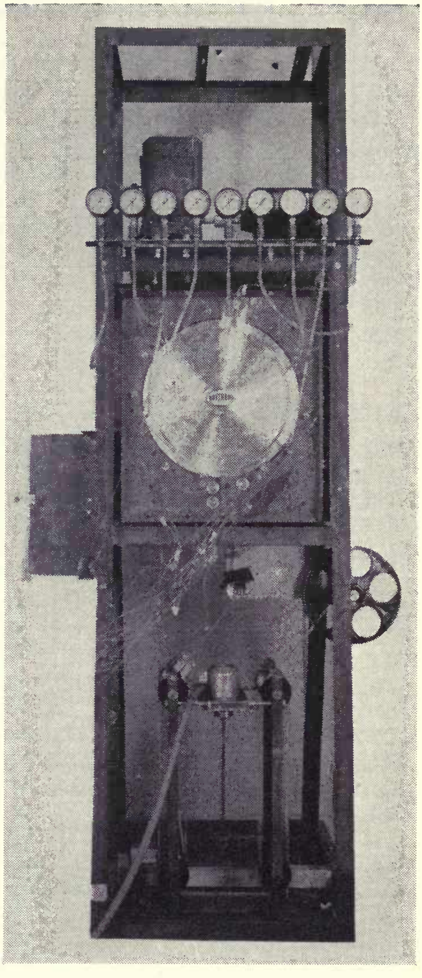

Fig. 6. Experimental setup of Raytheon K-3 film drier with water tank removed showing the film-wetting assembly.

After the demonstration this unit was returned to Raytheon for further study and an extensive experimental program was begun to determine the exact characteristics of this unit. A test setup was made as shown in Fig. 6 in

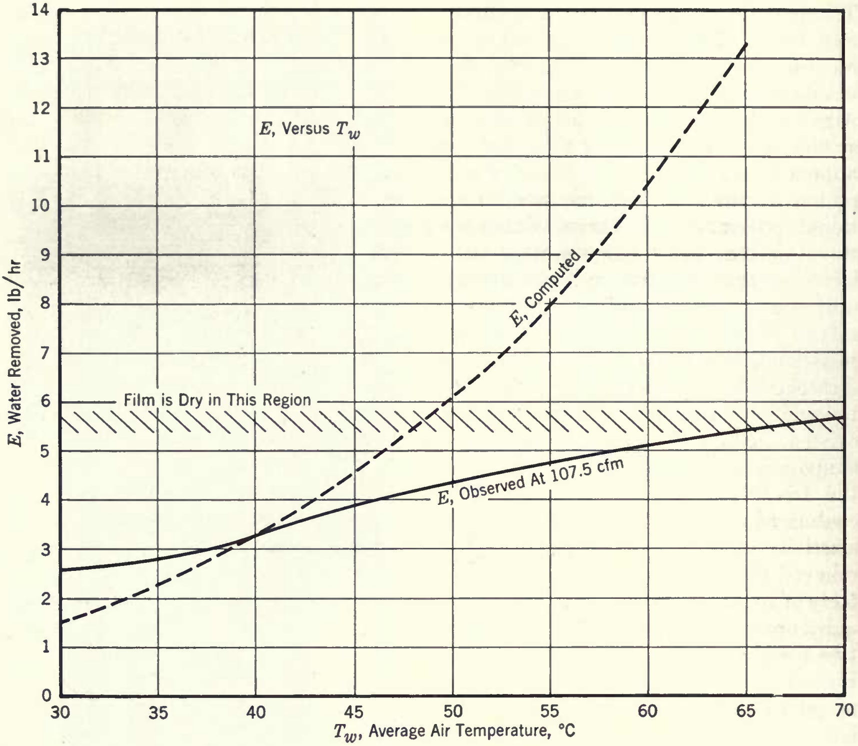

Fig. 7. Graphic representation of the theoretical and computed curves showing the amount of water evaporated from a specific length of film at given air temperatures.

which measurements were made of all the power going into the system, the total amount of water evaporated, and all the temperatures involved. The distribution of pressure and temperature was measured at a very large number of points along the wheel. As a result of these experiments it was found that the theoretical curve calculated from Eq. (12) and shown in Fig. 7 was not matched by the curve obtained in actual experiments.

An investigation of this discrepancy showed that the temperature of the film, and therefore the temperature of the water in the film, was considerably lower than the temperature of the air. It should be noted that the curve in Fig. 7 is plotted as a function of the average air temperature and it was believed initially that due to the use of the highly efficient turbulent air exchanger in the rear of the wheel, the wheel and film temperature would be equal to the air temperature. It was found, however, that the temperature difference between the air and the film was equal to the temperature drop encountered in the heat exchanger. Accurate measurements of the temperature of the wheel showed that the rate of evaporation followed the predicted theoretical curve within experimental errors, if the wheel temperature were plotted instead of the air temperatures. For instance, in the curve of Fig. 7, at an air temperature of 55 C, the wheel temperature was found to be 47 C; and at an air temperature of

65 C, the wheel temperature was found to be 48.5 C. This checks very closely with the computed curve. The deviation from the computed curve, as observed in the experiments, appears to be, therefore, solely a function of the temperature difference between the air and the wheel. It might be noted here that the difference in temperature between the wheel and film was very small and in the order of not more than 5 C.

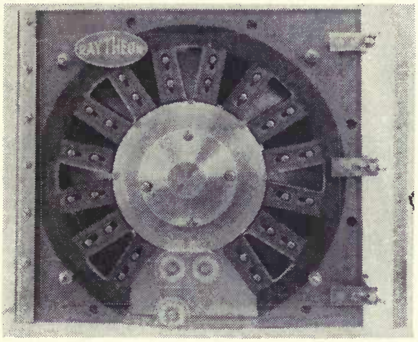

Fig. 8. Type K-4 turbulent-air high-speed film drier.

In order to assure operation of the wheel at the exact required temperature, a new model film drier (type K-4) was built as shown in Fig. 8. In this unit heating elements were installed in the wheel which were energized through slip rings. Approximately 2 kw of power was required to maintain the drum at the required temperature. The air was introduced directly into the slots in the rear of the unit and was forced over the film in a number of passages and exits in the front. The passages are formed by a number of movable blocks so that the duct width of the passage over the film can be varied. The diameter of this wheel was reduced to 6 in. from 16 in., since the calculations indicated that this would be sufficient to dry the film.

Satisfactory results were obtained with the K-4 film drier and considerable experimental data were obtained drying film at 100 fpm. However, an insufficient safety factor was allowed to permit the use of greatly different types of film. Up to this point the only film that had been used for the experiments was Du Pont Film, Type 628B. It was found that the amount of moisture which could be absorbed in the film during the photographic process varied considerably with different batches of film, with the amount and type of developer used, and with the amount of light exposure on the film.

In order to perform satisfactory experiments all tests described above were done with undeveloped film which was soaked in a wetting tank at constant temperature. It was found that only under these conditions could reproducible results be obtained.

The final design of a turbulent-air film drier which permits a sufficient safety factor for the use of almost any film of the 35-mm type is shown in Figs. 9 and 10. This unit (model K-6) incorporates a 14-in. wheel with approximately 3 kw of heaters inside the wheel

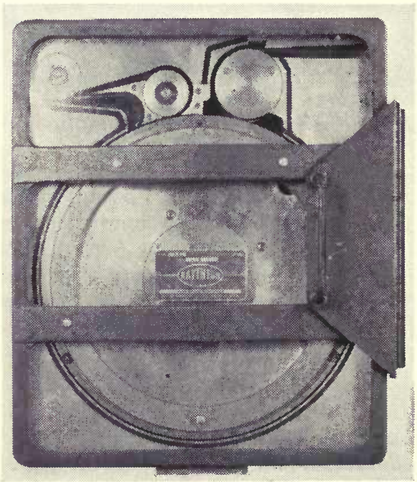

Fig. 9. Type K-6 turbulent-air high-speed film drier.

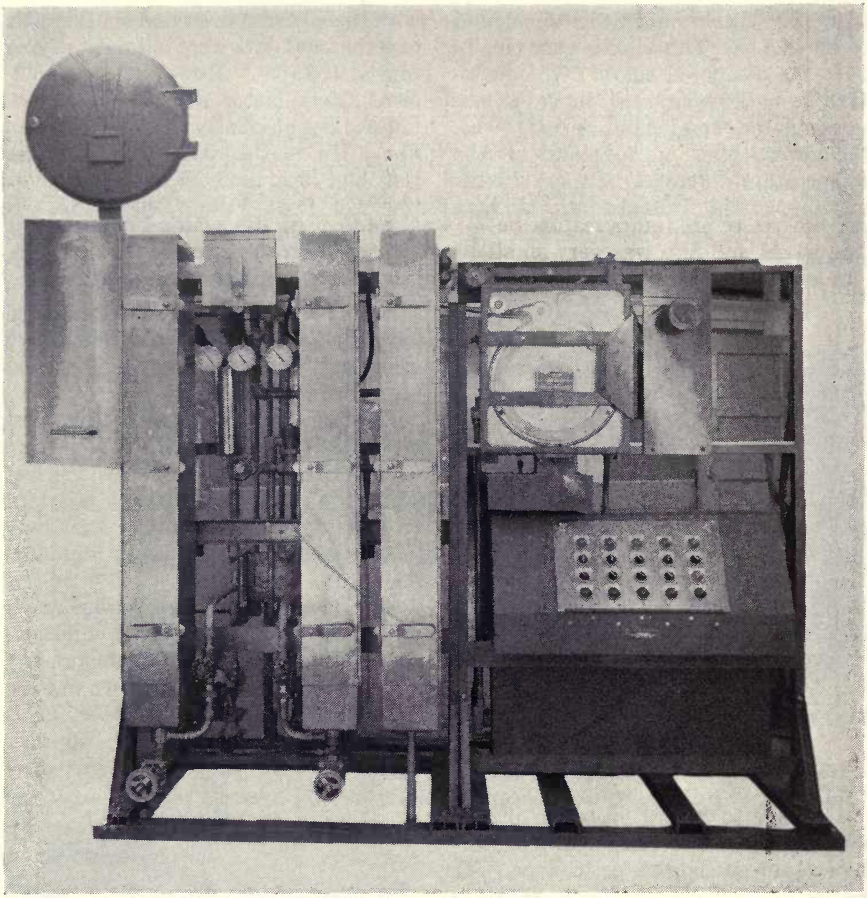

Fig. 10. K–6 film drier installed on Paramount Theater-Television Unit.

and approximately 2 kw of heat supplied to the air. A small Standardaire blower driven by a 3-hp motor delivers approximately 100 cfm at 5 psi. The capacity of this unit in water evaporated is approximately 10 lb/hr. Figure 10 shows this unit as mounted on the Paramount Theater-Television Unit.

Distortion

At the initiation of this project considerable doubt existed as to the possibility of survival of the emulsion when subjected to high-velocity air streams. It was believed that if the air velocity became too great the emulsion might be stripped off the film or that damage to the emulsion might result.

Although a large number of experiments have been performed in which air velocities have been observed as high as 550 mph over the film, not a single case of damage to the emulsion has been observed. On the contrary, measurements made at the Optical Research Laboratory, Boston University, with film dried in the Raytheon K-3 film drier, indicated that the distortion was considerably less than the distortion obtained by drying film by other means. It is

therefore believed that this method of film drying may be especially applicable where low distortion is of importance. It is believed that the freedom from distortion is the direct result of the uniformity of application of the turbulent air and of the rapidity with which the water is removed. Therefore all film shrinkages are uniform.

Application of Turbulence to Other Diffusion Problems

The general theory of diffusion can be applied to many other problems wherever the stagnant layer is the controlling rate factor in the diffusion problem. A number of different equipments have therefore been built for various applications using turbulent gases and fluids. It appears that turbulent air is an excellent medium to increase greatly the drying speed of most material in web form.

A very important application was found in the possibility of increasing the speed of photographic development, including the actual developing, fixing and washing. The speed of the photographic development process is greatly influenced by the speed of diffusion of various liquids into and out of the gelatin. It was found that a considerable increase in speed could be obtained by passing the developing, fixing and washing fluids over the film in turbulent form. These experiments will be the subject of a later paper.

Conclusions

A number of film driers have been developed in which turbulent air is used as a drying medium. It appears that satisfactory results can be obtained with such a unit in the ultrarapid drying of standard motion picture film in an extremely compact space. It was found that a wheel 14 in. in diameter will be satisfactory for film speeds up to 100 fpm. It was also found that the distortion in the film with this method of drying is very low.

Acknowledgments

Part of the work described in this paper was done in cooperation with Richard Hodgson of Paramount Pictures, Inc., whose valuable help and suggestions contributed greatly to its success. The unit 16 in. in diameter, shown in Fig. 5, was mounted on the Paramount 35-mm theater-television equipment and demonstrated in Hollywood for the TOA Convention at the Ambassador Hotel in September 1949. Approximately 26,000 ft of 35-mm film was processed through the 16-in film drier at a rate of 90 fpm during this convention with satisfactory results.

Part of the work described in this paper was done in cooperation with the Optical Research Laboratory, Boston University, with the assistance of Dr. D. E. Macdonald and Dr. R. C. Gunter, Jr., from that laboratory. The theoretical derivations described in this paper are based on the teachings of Prof. J. Kaye, Massachusetts Institute of Technology, whose valuable consulting services greatly helped in the speedy solution of many problems. The assistance of J. W. Belcher, W. F. Esthimer and J. F. Moore, who helped in the design of equipment and performance of the experiments, is gratefully acknowledged.

Bibliography

1. A. R. Burkin, "Ultra-rapid processing of photographic materials," *Phot. Jour.*, vol. 87B, pp. 108–111, 1947.
2. F. E. Tuttle and C. H. Green, "Photographic race-timing equipment," *Jour. SMPE*, vol. 27, pp. 529–536, Nov. 1936.
3. H. A. Miller and J. I. Crabtree, "Combined developing and fixing solutions," *Amer. Phot.*, pp. 76–79, Feb. 1948.
4. J. I. Crabtree, "Rapid processing of films and papers," *J. Phot. Soc. Amer.*, vol. 15, pp. 130–136, Feb. 1949.
5. F. M. Brown, L. L. Blackmer and C. J. Kunz, "A system for rapid production of photographic records," *J. Frank. Inst.*, vol. 241, pp. 203–212, Sept. 1946.

6. "Dimensional stability of film," Boston University Optical Research Laboratory, Technical Note No. 55, July 8, 1949.
7. John C. Johnson, "Measurement of the surface temperature of evaporating water drops," *J. Appl. Phys.*, vol. 21, Jan. 1950.
8. J. Kaye, J. Keenan and William McAdams, "Measurements of friction coefficients, recovery factors and heat transfer coefficients for supersonic flow of air in a pipe," M.I.T. Technical Report No. 6418-1, June 1, 1949.
9. "Dimensional changes of topographic film in four drying methods," Boston University Optical Research Laboratory, Technical Note No. 10, Jan. 1948.
10. B. L. Harris, "Absorption," *Ind. Eng. Chem.*, vol. 42, no. 1, pp. 20–24, Jan. 1950.
11. Robert L. Pigford, "Absorption and humidification," *Ind. Eng. Chem.*, vol. 42, no. 1, pp. 17–19, Jan. 1950.
12. Samuel J. Friedman, "Drying," *Ind. Eng. Chem.*, vol. 42, no. 1, pp. 38–44, Jan. 1950.
13. Von R. Gran Olsson, "Geschwindigkeits-und Temperaturverteilung hinter einem Gitter Bei turbulenter Stromung," *Z.A.M.M.*, vol. 16, pp. 257–274, 1936.
14. K. J. Laidler and K. E. Shuler, "The kinetics of membrane processes: I. The mechanism and the kinetic laws for diffusion through membranes; II. Theoretical pressure-time relationships for permeable membranes," *J. Chem. Phys.*, vol. 17, No. 10, pp. 851–865, Oct. 1949.
15. Franz Elias, "The transference of heat from a hot plate to an air stream," *NACA TM-614*, Apr. 1931.
16. E. Forthmann, "Turbulent jet expansion," NACA TM-789, Mar. 1936.
17. C. Ferrari, "The transport of vorticity through fluids in turbulent motion," NACA TM-799, July 1936.
18. H. Reichardt, "Heat transfer through turbulent friction layers," NACA TM-1047, Sept. 1943.
19. J. H. Arnold, "Studies in diffusion: I. Estimation of diffusivities in gaseous systems, *Ind. Eng. Chem.*, vol. 22, p. 1091, 1930.
20. B. A. Bachmeteff, *Mechanics of Turbulent Flow*, Princeton Press, 1936.
21. P. Y. Chou, "On an extension of Reynolds' method of finding apparent stress and the nature of turbulence," *Chinese J. Phys.*, vol. 4, pp. 1–33, 1940.
22. S. Corrisin and M. S. Uberoi, "Further experiments on the flow and heat transfer in a heated turbulent air jet," NACA TM-1865, Apr. 1949.
23. C. Ferrari, "The transport of vorticity through fluids in turbulent motion, *L'Aerotecnica*, vol. 15, pp. 1037–1056, 1935. Translated as NACA TM-799, July 1936.
24. J. Jaeger, "Diffusion in turbulent flow between parallel planes," *Quart. Appl. Math.*, vol. 3, pp. 210–217, 1945.
25. A. Page, "The behavior of fluids in turbulent motion," *J. Roy. Aeronaut. Soc. London*, vol. 37, p. 573, 1933.
26. E. Forthmann, "Über turbulente Strahlausbreitung," *Ingenieur-Archiv.*, vol. 5, pp. 42–54, 1934. Translated as NACA TM-789, Mar. 1936.
27. C. Ferrari, "Sulla Teoria della Turbolenza," *Rendiconti della Reale Accademia Nazionale dei Lincei*, p. 100, 1934.
28. H. Reichardt, "A new theory of free turbulence," *Z.A.M.M.*, vol. 21, pp. 257–264, 1941. Translated in *J. Roy. Aeronaut. Soc. London*, vol. 47, pp. 167–176, 1943.
29. G. D. Mattioli, "Sopra l'Influenza della Viscosita del fluido nei Regimi Turbolenti," *Atti della Reale Accademia* della Scienze di Torino, p. 220, 1935.
30. L. Prandtl, "Bermerking zur Theorie der freien Turbulenz," *Z.A.M.M.*, vol. 22, p. 241, 1942.
31. H. Reichardt, "Gesetzmassigkeiten der freien Turbulenz," VDI Forschungsheft 414, May-June 1942. Reproduced as ARC 6670, FM 586.
32. H. W. Liepmann, S. Corrisin and J. Laufer, "Some measurements in free turbulent shear flow," *Sixth International Congress for Applied Mechanics*, Paris, 1946.
33. G. D. Mattioli, "Teoria della Turbolenza," *Rendiconti della Reale Accademia Nazionale dei Lincei*, vol. 17, p. 217, 1933.
34. H. Reichardt, "Heat transfer through

turbulent friction layers," *Z.A.M.M.*, vol. 20, pp. 297–328, 1940. Translated as NACA TM-1047, Sept. 1943.

35. G. D. Mattioli, "Dissipazione Verticose nei Regimi Turbolenti," *Rendiconti della Reale Accademia Nazionale dei Lincei*, p. 87, 1935.
36. L. Prandtl, "Bericht über Untersuchungen zur ausgebildeten Turbulenz," *Z.A.M.M.*, vol. 5, pp. 136–137, 1925.
37. H. Rouse, "Modern conceptions of the mechanics of fluid turbulence," *Trans. Amer. Soc. Civil Engr.*, vol. 102, p. 463, 1937.
38. T. K. Sherwood, *Absorption and Extraction*, McGraw-Hill, New York, 1937.
39. L. F. Stutzman, "Mass transfer in turbulent flow," doctoral dissertation, University of Pittsburgh, 1946.
40. T. K. Sherwood and B. B. Woertz, "The role of eddy diffusion in mass transfer between phases," *Trans. Amer. Inst. Chem. Engr.*, vol. 35, p. 517, 1939.
41. G. I. Taylor, "Statistical theory of turbulence," *Proc. Roy. Soc. London*, vol. A151, pp. 421–478, 1935.
42. H. B. Squire, "Reconsideration of the theory of free turbulence," RAE Farnborough, Report No. Aero 2023, Mar. 1945. Abstract in *Philosophical Magazine*, vol. 39, pp. 1–20, Jan. 1948.
43. T. K. Sherwood, "Mass transfer and friction in turbulent flow," *Trans. Amer. Inst. Chem. Engr.* vol. 36, p. 817, 1940.
44. Walton Forstall, Jr., "Material and momentum transfer in coaxial gas streams," doctoral thesis, Massachusetts Institute of Technology, Course II, 1949.
45. T. von Kármán, "Some aspects of the turbulence problem," *Proc. Fourth International Congress for Applied Mechanics*, pp. 54–91, 1934.
46. K. Victorin, "Untersuchung turbulenter Mischvorgange," *Forschungsarbeiten auf dem Gebiete des Ingenieurwesens*, vol. 12, p. 16, 1941.
47. J. S. Hall, A. Mayer, and G. Maslach, "A 16-mm rapid film processor," *Jour. SMPTE*, vol. 55, pp. 27–36, July 1950.
48. C. E. Ives and C. J. Kunz, "Simplification of motion picture processing methods," *Jour. SMPTE*, vol. 55, pp. 3–26, July 1950.

DISCUSSION

F. N. Gillette: You mentioned that the turbulent fluid processing was considerably faster. Faster than what? How does it compare with the spray type of processing used in the Paramount equipment?

Mr. Katz: That is a difficult question to answer. The developing time in general has been rather vaguely defined. In order to get around that problem we set up our experiments as follows: The system consists of a chamber in which our photographic film wedge is suspended and we pump liquid developer out of a reservoir through the chamber and back into the reservoir again. We measure the temperature, pressure and velocity of the liquid developer so that we know the Reynolds number in the chamber over the film. We then compare the speed of developing under turbulent conditions with the speed of developing required by a similar photographic wedge hung in the reservoir under stagnant conditions. There is mild agitation in the tank under those conditions through liquids being pumped around. The ratio between the developing time under stagnant conditions and the developing time under turbulent conditions is called the improvement factor. It is a little early really to comment on this method since we have run only about 150 films through this turbulent chamber. The encouraging factor, however, is that the improvement appears to be a linear function of the Reynolds number and we have not found a leveling off of the curve anywhere.

E. W. Kellogg: [*condensed*] I want to ask Mr. Katz about the static film theory. I understand that a number of years ago Langmuir, during the development of the gas-filled incandescent lamp, concluded that in the circulating atmosphere around hot filaments there was a stationary film whose thickness was cut down by the rapidity of the current. Do you know of any evidence to prove whether there really

is a stationary film with a fairly definite thickness?

Mr. Katz: The thickness of the static film can actually be determined. It has been found that ultrasonic waves will also destroy the stagnant layer.

Dr. Kellogg: How do you know that the layer is really stagnant, with a definite boundary surface between it and the region of turbulent flow?

Mr. Katz: The only good answer we have for this is that the theory has not yet been disproved and everything we have found so far seems to follow the theory accurately. We don't measure the stagnant layer directly but indirectly by the results which we get, and everything that we have done so far lies within experimental error of our theory. Until the theory is disproved we more or less assume that we are right.

Robert M. Corbin: Mr. Katz, I have one point I would like to make. In your first illustration, you showed film base as being more or less an inert material, which is far from the fact. In your process, I don't think this enters in at all, but if anyone should try to dry a film by your method after the conventional processing, they might get involved in some difficulty on account of the amount of moisture taken up by the film base. There is very little, if any, taken up in the rapid processing method; but if you had the film base saturated with moisture, and you didn't make a very great effort to drive the moisture out, at least to the same equilibrium at which you are going to keep the film, you would get differential drying in the roll and a buckling effect which has been encountered in the old type of processing in the past with disastrous results. So, this type of drying should be reserved for rapid processing, or at least modified to take care of moisture absorption if used with other types of processing.

Mr. Katz: The unit which we have built for Boston University under subcontract for the Air Forces takes 9½-in. wide super XX film which has a very heavy emulsion. The film is processed by conventional means with a total processing time of approximately 4 hr in which it is continuously immersed in liquid. It is then dried in the machine at a rate up to 70 fpm and comes out totally dry.

Mr. Corbin: My point is concerned with motion picture film particularly. If you roll it up on the reel, the film is under fairly high tension. You don't get drying in the center of the roll as rapidly as in the outside windings and you can also get the outside to dry down more rapidly and cause a sort of baggy effect in the center. Your edges become shorter than the center, with a buckling effect on the screen when you project it. There would not be a problem with anything like Aero film.

Mr. Katz: We have measured distortion rather carefully on Aero film. Very fine grid is superimposed on the film and then analyzed. We have found no such distortion as you mention.

Mr. Corbin: The distortion I am speaking of doesn't take place at the time of drying. It takes place during storage under rather high tension of rewinding, which is generally used for motion picture film. It is not a question of distortion at the time of drying, but of distortion effects after the ultrarapid drying.

Mr. Katz: We have not run into anything of that nature yet. It may be ahead of us.

John G. Stott: I have a couple of questions which I think could be tied up with one answer. Do you have any data on horsepower consumption of drying by this method compared to conventional methods?

Mr. Katz: The horsepower rating of the unit which is presently installed in the Paramount Theater-Television Unit is 7½ kw. The horsepower rating will always go up as the speed of drying increases since a certain amount of heat of evaporation must be supplied.

Mr. Stott: Do you preheat your air?

Mr. Katz: Yes, we preheat both our air and our wheel. The reason for that is that in the evaporation process both the air and wheel will cool off and if we don't heat the air and the wheel the film will be cooled to a point of excessive brittleness and break.

Mr. Stott: I also notice in your paper the conspicuous absence of data on relative humidity. Does it have any particular effect?

Mr. Katz: The satisfactory operation of the unit is independent of relative humidity of the air.

Mr. Stott: In other words, you get dry film with essentially saturated air.

Mr. Katz: We have done that, yes.

H. J. Schlafly: You give figures of pressure and air on the first model. Do these hold true for the latest design?

Mr. Katz: No, they vary. The latest design uses a thinner opening than the first model. The latest design operates at 4½-lb pressure and something in the vicinity of 80 cfm for the total air consumption.

Mr. Schlafly: What are the requirements on the blower?

Mr. Katz: The actual horsepower required for the blower is approximately 3 hp. We have a 5-hp motor installed just to be safe.

Mr. Stott: Mr. Hodgson, with regard to your demonstration reel, truthfully I was astonished when you said that the first reel was processed by conventional means, whereas the last one was processed on your hot machine, because I have done some work in this rapid processing and have noticed that one of the effects (I wouldn't call it a defect) of the hot processing is considerable sharpening of the toe region of the sensitometric curve instead of a long sweeping toe, which is characteristic of 5302. It tends to sharpen it, which usually shows up as more glaring highlights, and I definitely thought that the first film, on the basis of its highlights, was the rapid processed one. Secondly, the rapid processing tends to create or produce very much of a blue-black tone as compared with the cold process, and once again I was fooled on that basis, because I thought the first film was rapid processed and the second one processed conventionally. Do you have any comments to make on that?

Richard Hodgson: Not particularly. The first portion was done by conventional 40-min processing. The last section was done in 25 sec.

Mr. Stott: Do you have any sensitometry on this?

Mr. Hodgson: No.

Voice: I have come to the opposite conclusion. Viewed from this distance, the second one had definitely more contrast. Also, the second one had more blue-black.

Mr. Stott: I don't think I was at optimum viewing position down here, but I got exactly the opposite reaction from yours. How did somebody in the middle feel about it?

Voice: We couldn't tell the difference.

Mr. Hodgson: Well, that is what we like to say. We would like to project them side by side too, but the facilities here don't lend themselves to this. The best we could do was to give you the photomicrograph slides in rapid succession for what that indicates in grain size. It doesn't take care of the other factors which you mention, however.

George Lewin: Mr. Hodgson, do you happen to know whether this sound track was variable density or variable area?

Mr. Hodgson: Area.

Mr. Lewin: Do you have any data as to whether either type of track will respond to this treatment in the same way?

Mr. Hodgson: We normally use variable density. This negative happened to be variable-area track and we handled it the same way that we handled variable-density track. In other words, we developed it to a density of 0.2. We gave it no special treatment.

Mr. Lewin: Would you say that you can treat the negative just as successfully, or just the print?

Mr. Hodgson: We make more negatives in the course of our recording of television shows than we do positives by about a factor of 7 to 1, and they are handled by the same method—different formulas, but the temperatures are the same.

Norwood L. Simmons: [*Question to Mr. Katz*] We assume that your remark that saturated air can be used must have applied to air saturated prior to its heating?

Mr. Katz: That is correct.

Dr. Simmons: Secondly, from the front row I did note what I thought to be considerably more density fluctuations in the second print—nonuniformity, or what you might term not mottled, but some weaving density fluctuations which appeared just at the start. Did anyone else have such a feeling?

[*Several hands were raised.*]

Dr. Simmons: There were several others who didn't seem to have the courage of their convictions when you asked for a vote.

C. R. Fordyce: I'd like to ask Mr. Katz what maximum temperature the air reaches in the drying operation, and what temperature the film reaches?

Mr. Katz: There are a number of units in operation at the moment, not all of them are alike. In general, we try to maintain the film at a temperature of approximately 55 C. The air temperature varies depending on the design of the unit. If there is a heat exchanger in the rear it has to enter very much hotter to maintain the wheel temperature at the desired level of 55 C. In general, we try to maintain the air over the film at a temperature of 70 C. With the air running over the film at 70 C, the temperature of the film will remain at 55 C.

J. A. Tanney: In answer to the question about the buckling effect or the in-and-out effect that you might get when viewing the projected picture, have you ever tried any of those films that have been in storage or which have been wound and rewound?

Mr. Katz: As far as the 9½-in. film drier is concerned, we have stored 9½-in. film for a considerable length of time after it has been dried in the machine, and we have not been able to find any difficulty so far. Maybe we haven't stored it long enough or reeled it and unreeled it enough. The film in the machine, however, gets wound up after considerable tension.

Mr. Tanney: I was referring to motion picture film. I don't suppose you have done much of that.

Mr. Hodgson: The first real chance to observe this came when the first turbulent drier was used in connection with the demonstration we made last October in Los Angeles for TOA, and that reel or series of reels which we dried then we have shown to people as recently as last August, which was almost a full year later, and the projectionists have reported no trouble in running it through. It seems to handle just as a normal reel.

Dr. Kellogg: One more question occurs to me. What provisions do you make for keeping your air clean? It seems to me that this violent blowing would tend to deposit dust on your film unless some rather extraordinary filtering precautions were taken, or else re-using the air after precipitating out the moisture.

Mr. Katz: We have had that problem, especially at the point where the air is first introduced on the film. At that point the air has to go around a corner and any particles in the air would hit the film straight on. In our 9½-in. wide film drier we found that pitting of the film would occur if we purposely blew sand into the machine. Sufficient filtering, however, was obtained by means of an ordinary air filter similar to the one used in an automobile engine.

Supplementary Discussion*

The stagnant-layer theory is specifically based on the principle that the speed of diffusion of the liquids through the gelatin or other solids is sufficiently great so that the surface can always be assumed to be wet. If the surface of the gelatin is wet then the only resistance to diffusion will be posed by the thickness of the stagnant layer. At low temperatures the driving force is relatively small and the entire resistance to evaporation is governed by the thickness of the stagnant layer. The rate of evaporation will still be relatively small at low temperatures even if the stagnant layer is reduced because the driving force is relatively small. Of course, reduction in the stagnant layer will bring about a proportional increase in the rate of evaporation. Consequently, if, for instance, at low temperature the normal drying time for one section of film were 1 hr, and the stagnant layer were reduced to ⅓₀ of its thickness by the application of turbulent air, then the drying time would be reduced to 2 min.

Inasmuch as the rate of evaporation is still relatively low, the rate of diffusion of the liquid through the gelatin is so small that the surface can be assumed to be wet at all times. If, however, the temperature is now raised, which increases the driving force, the rate of evaporation will be increased to a point

* Communicated by the author on December 14, 1950, in order to clarify points raised during the discussion.

where the diffusion through the gelatin itself will become the limiting factor, i.e., a point may be reached in which the surface layer of the gelatin closest to the gas side is relatively dry, whereas the bottom of the gelatin closest to the base of the film would be relatively wet.

The problem is then resolved into a transient diffusion problem in which a humidity gradient is set up through the gelatin. This humidity gradient will only become important when the rate of evaporation has been greatly increased. It was found experimentally that this limit becomes apparent when positive-type stock is dried in a time shorter than 1 sec or when negative stock is dried in a time shorter than 2 sec. In general, therefore, film driers must be designed in such a fashion that the emulsion of the film is exposed to turbulent air for a period of not less than 2 sec. The actual film speed that can be obtained can, of course, be made as large as one wishes by simply increasing the time during which the film is continuously exposed to turbulent air.

With reference to the extremely low temperatures realized in the use of the first model, it can be stated that this was not originally anticipated. It was hoped that as a result of the turbulence the heat transfer between the air and the film would be sufficient to maintain the film at room temperature. However, it was found that approximately 40% of the heat was supplied from the air and 60% of the heat had to be supplied by direct conduction or radiation into the film itself. Consequently, the heating of the back side of the film was necessary to maintain the film at room temperature or higher.

With reference to the use of raw film in the experiments, I would like to explain that a large number of experiments were first made with processed film which had been run through Paramount's 35-mm machine. It was found, however, that small changes in the developer or hypo concentrations plus small variations in the thickness and quality of the emulsion itself produced variations in water absorption of the film of approximately 50%. As a result it was not possible to use processed film in the experiments, as consistent data could not be obtained. A number of experiments were then performed in which the total water absorption of the processed film was checked carefully and the total spread in the water absorption figures was carefully noted. The experimental determination of the rate of evaporation at various temperatures and Reynolds numbers of the air was then performed on raw stock which again had been carefully measured as to its water absorption qualities. It was found that the amount of water absorbed in the raw stock was to a great extent determined by the temperature of the water in which it was immersed. During the experiments the temperature of the water was maintained at a point where the water absorption of the raw stock was approximately equal to the water absorption of the processed stock. Adequate corrections were then made in the design of the film drier to produce a safety factor which would compensate for the spread in the water absorption qualities of the processed stock, so that even under the worst conditions processed stock could be dried in the required time. Spot checks were made at various points during the experiments with the processed film to compare the result between processed film and raw stock at a number of points in the curves.

With reference to the type of film distortion which was measured and the methods used for measurement, I would like to defer the discussion of this to a later paper which is now in preparation in cooperation with Dr. R. C. Gunter of the Optical Research Laboratory, Boston University. Also, additional details concerning the actual design of film driers and general design charts will be presented in that paper.

Television Transmission in Local Telephone Exchange Areas

By L. W. Morrison

The functions of a video transmission system in a local exchange area in providing mobility for the pickup camera and interconnection with the intercity networks are discussed; and an analysis of some of the television transmission problems is presented. A description is given of the physical and electrical characteristics of the various types of cable facilities, the video amplifiers, and equalizers now employed; and an example of the television transmission performance obtained is included.

THE TELEVISION transmission distribution system in the local exchange area fulfills a most necessary function in the over-all television broadcasting system. The sole purpose of network broadcasting is to attract the greatest possible audience. The local video distribution system, as the means whereby the initial and final connection is accomplished, contributes to the efficiency of the network pattern in two ways: first, it allows greater mobility for the pickup camera, thus permitting a wider range of subjects and more attractive program material to be offered to the public; and second, it furnishes the means by which the program may be made available to viewers far outside the present restricted coverage of a television broadcast transmitter. In the future, it is believed, the local television system may in a similar fashion contribute to efficient distribution of televised material for theater consumption.

At present, the local video system is called upon to furnish the connection between the remote pickup camera and the master control area of the local studio, the connection between the studio and its local broadcast transmitter location, and the connection between the studio and the intercity network facility.

It is apparent that we are here dealing with a transmission facility which has two unique characteristics. First, we are concerned with relatively short distances, say 1000 ft to 20 miles; and second, the system is entirely a point-to-point transmission medium as contrasted with area coverage of the usual broadcast transmitter. In addition, the very nature of the function dictates that privacy of the connection be assured.

The Bell System presently employs both wire and microwave television transmission methods in the local telephone exchange area. The choice of medium here, as always, is one of

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economics. For example, in the Los Angeles, Calif., area all television broadcast transmitters are located on a mountain range overlooking the metropolitan area, approximately 20 miles from the Hollywood location of most studios. The terrain is such that microwave methods have an overwhelming advantage over wire circuits for the main circuit, though even here the final connections to the various broadcast transmitters on the mountain are made by wire circuits just as the studio-to-Hollywood Central Office pickup connection is made. In many other metropolitan locations the microwave line-of-sight requirement is difficult to achieve and in these cases wire television facilities are almost exclusively employed. In our opinion, wire and microwave television transmission techniques will tend to complement rather than compete in the service of providing a sound economic local point-to-point television connection.

The following discussion will be confined to the local telephone exchange area television transmission systems employing wire as the transmission medium. It is proposed to analyze the problem considering the terminal conditions, the characteristics of the cable plant, and the gain and equalization required. A description of the equipment now in use will be followed by a discussion of typical performance obtained.

Terminal Conditions

The television studio equipment which represents one terminal condition for a local video interconnection is generally operated on a 75-ohm unbalanced-to-ground impedance basis. This is a matter of economy of components and within the restricted confines of a studio area is permissible since the signal levels are relatively high and the transmission distances involved are small.

In the telephone plant where greater lengths of exposure to interfering electrical fields are the rule, the balanced-to-ground impedance is universally employed. The characteristic impedances of telephone cables which are available for video transmission purposes range from 90 ohms to about 140 ohms. The equipment design at present is based on a balanced impedance of 110 ohms.

The signal level available at the studio for transmission over a local interconnecting circuit has been generally of the order of 2 v peak-to-peak and the input level required at a television broadcast transmitter or at the input to the studio master control equipment has varied from 0.25 to 1 v peak-to-peak.

The signal level which is impressed on the telephone cable is maintained at the highest possible economic value to insure the best signal-to-noise performance. At present the common signal amplitude at the input terminals of a cable is generally of the order of 2 v peak-to-peak. In the television operating centers which represent the terminals of the intercity network a standard level of 1 v peak-to-peak across 110 ohms has been adopted.

The local video transmission equipment then must provide for the conversion of the signal from the form available at the terminal ends to one suitable for transmission over the telephone cable. This involves treatment of both impedance and signal levels.

Telephone Cable Characteristics

The character of the transmission medium exerts the primary influence on the design of the bulk of the equipment employed in local video interconnecting circuits. The characteristics involving impedance, attenuation versus frequency, and the shielding, as well as the pair location with respect to sources of induced unwanted interference, must be considered. The impedance and attenuation characteristic dictate the

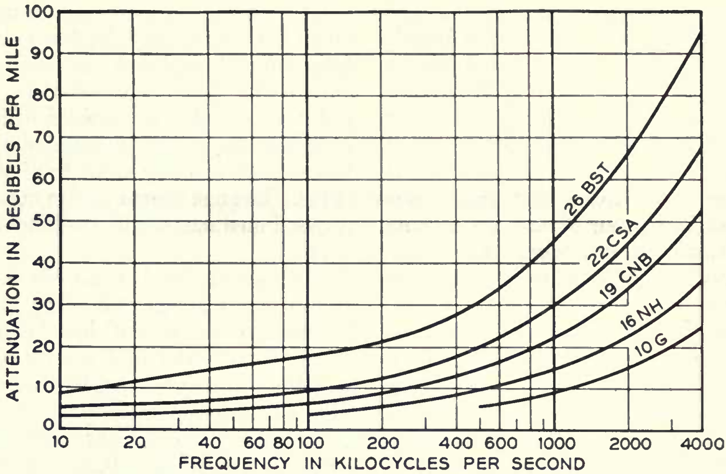


Fig. 1. Attenuation of paper-insulated cables at video frequencies.

type of termination to be employed and the degree of equalization required. The shielding properties of the cable, together with a knowledge of the degree of exposure to sources of interference, finally set the signal-to-noise performance of the circuit.

A wide variety of paper-insulated interoffice and subscriber cables exist in the telephone plant. Gauges ranging from No. 10 to No. 26 are employed with many available routes consisting of a composite of these. Figure 1 shows the attenuation-frequency characteristics for a number of cables which have been used for video purposes in the past. The loss at 4 mc (megacycles), which must be compensated for by equalization and gain, varies from about 25 to 95 db/mile for the types shown.

These paper-insulated pairs are adjacent to others, perhaps as many as 1800 in a single lead sheath, and are therefore subject to induced interference from signals in these associated message circuits. Impulse-type noise is commonly transmitted over a message circuit resulting in large measure from the complex switching operations of the modern telephone plant. In addition, low-frequency signals may be induced into the video pair from neighboring power circuits.

The minimum level to which the video signal may be attenuated involves the total interference level at hand and a signal-to-noise performance objective. With this information and a knowledge of the maximum undistorted power output of the video repeater or the transmitting terminal, the maximum usable gain required is determined. Then by a consideration of the attenuation characteristic of the cable, the repeater spacing may be computed.

For the paper-insulated pairs under consideration, impulse-type noise generally is controlling, and repeater gains of about 65 db result. For No. 26 gauge this will result in a repeater spacing of about 0.7 mile.

There is finally another restriction in the maximum gain which can be used in a video repeater. The coupling between the input and output of the repeater must be limited if unwanted regeneration effects are to be minimized. This coupling from output to input terminals via adjacent pairs limits the gain usually to the order of 40 db. This

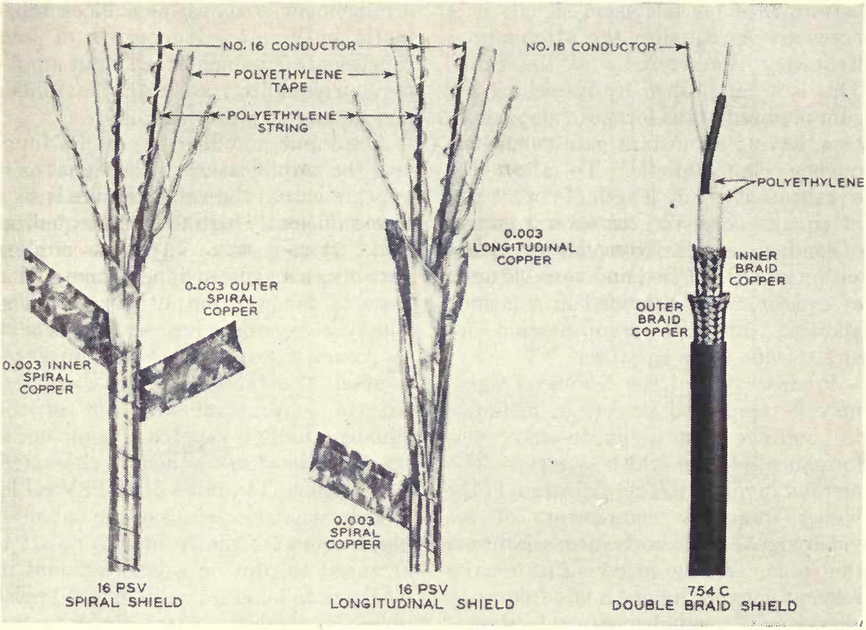


Fig. 2. Construction of shielded video cables for local exchange area use.

situation may be remedied by the use of separate cable sheaths at the input and output of each repeater.

At the present time the majority of video interconnecting circuits in the local exchange area employ a special shielded pair for transmission, thus reducing materially the restrictions present with paper-insulated telephone cables just discussed. Figure 2 illustrates the mechanical features of construction of some of these shielded television pairs.

The 16 PSV (polyethylene shielded video) pair uses polyethylene string and tape to support the 16-gauge conductors within a copper shielding tube. As shown, both spiral copper tape and a combination of spirally wound tape and a longitudinal seamed tube have been employed. Such a conductor is composited directly into an interoffice cable replacing about 20 of the paper-insulated pairs. A number of such 16 PSV conductors may be placed within a common lead sheath, the improved shielding allowing their use simultaneously in either direction for transmission.

For interior wiring within the central office and at the terminal ends of the circuit, as well as for temporary short outside routes, the double-braided flexible cable shown in Fig. 2 has been extensively employed. This cable has a solid polyethylene extruded core containing two No. 18 conductors.

The attenuation-frequency characteristic of the polyethylene dielectric type of video cables is given in Fig. 3.

When the shielded video cable is used the impulse-noise level is greatly attenuated and the allowable repeater gains may be increased. With an attenuation of 17 db/mile, as indicated in Fig. 3, it allows repeater spacings upward of 5 miles to be employed.

To provide adequate transmission

performance for television signals it is necessary to equalize the attenuation-frequency characteristic of the cable. This is accomplished by furnishing the gain required in the form of video amplifiers, having a constant gain-versus-frequency characteristic. To allow the equalization of any length of circuit and of circuits consisting of several gauges of conductors a variable plan for equalization is used. Fixed and variable units of equalizers are provided in a fashion allowing adequate compensation for any specific cable situation.

Predistortion of the television signal may be employed in certain instances to improve the signal-to-noise performance of the video system. The method involves the amplification of the higher frequency components of the video signal prior to transmission over the cable. At the receiving terminal a restorer network having a loss-frequency characteristic complementary to that of the predistorter is introduced. The signal is unaffected by transmission through these two networks while noise introduced into the cable circuit is attenuated by the restoring network. Figure 4 indicates the characteristics of the predistorter and restorer networks. An impulse-noise improvement of about 16 db is realized in practice.

Equipment Description

There are three basic equipment units which are required in a local wire television transmission installation. These include a transmitting terminal, a repeater, and the receiving terminal. The primary function of the transmitting and receiving terminals is one of conversion of the signal from the customer's equipment to a form suitable to the cable pair in the telephone plant. The repeater unit furnishes the bulk of the gain required to overcome the transmission loss of the cable and the means to properly equalize its loss-frequency characteristic.

The Video Repeater. The repeater arrangement is shown as a block schematic in Fig. 5. It consists of four functional components: an input amplifier, an equalizer, an output amplifier and necessary power supplies.

The input amplifier has as its function the amplification of the signal as it appears across the cable terminals to a level sufficiently high to permit equalization. It consists of an input coupling network, a balanced input stage and a cathode follower output circuit. The coupling network has a gain-versus-frequency characteristic which increases to about 13 db at 4 mc. This characteristic in conjunction with one of the equalizer units is capable of compensating for the loss-frequency characteristic of about 1⅓ miles of 16 PSV cable.

The schematic details of the balanced input stage are shown in Fig. 6. It is arranged to provide a large amount of feedback to longitudinally induced noise voltages which arrive at the repeater. The longitudinal suppression here obtained is of the order of 75 db at low frequencies, the region of the most troublesome noise conditions. In addition, impedance balancing controls are provided to further minimize these effects. The voltage gain of this input amplifier is about 14 db and the output circuit is arranged to connect directly to the following equalizers on a 1000-ohm impedance basis.

The equalizer portion of the video repeater consists of three types of units: a basic equalizer whose loss-frequency characteristic in conjunction with the input amplifier coupling network will compensate for about 25 db of 16 PSV cable loss at 4 mc; a variable unit which will equalize 10 db of cable loss in 1-db steps and the fixed equalizer which will equalize a 10-db section of 16 PSV cable.

By using one or more amplifier coupling networks, and basic, variable and fixed equalizers, we have the means to provide equalization of any specific length of cable—limited finally by the gain capabilities of the repeater.

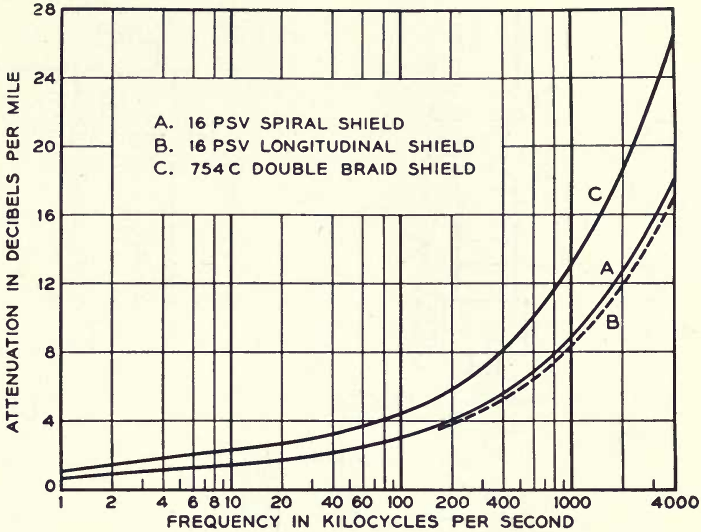


Fig. 3. Attenuation of shielded video cables.

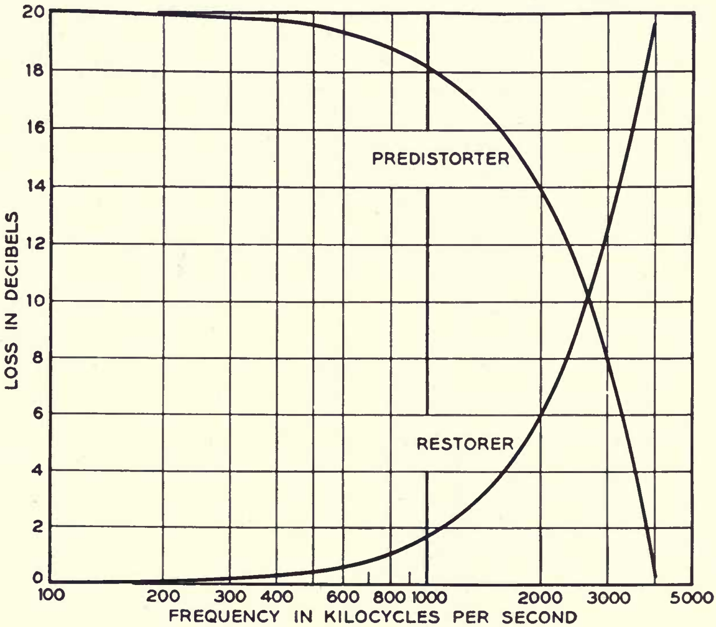


Fig. 4. Loss-frequency characteristics for predistorter and restorer networks.

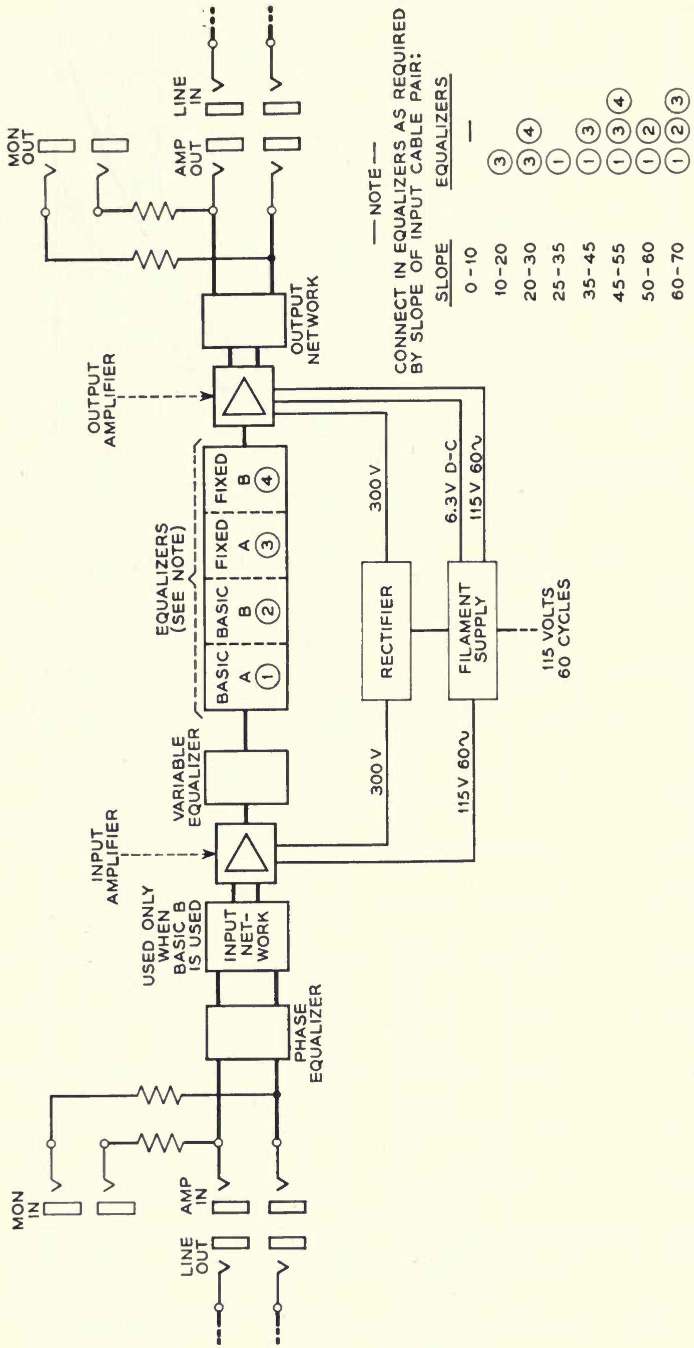


Fig. 5. Video repeater—block schematic.

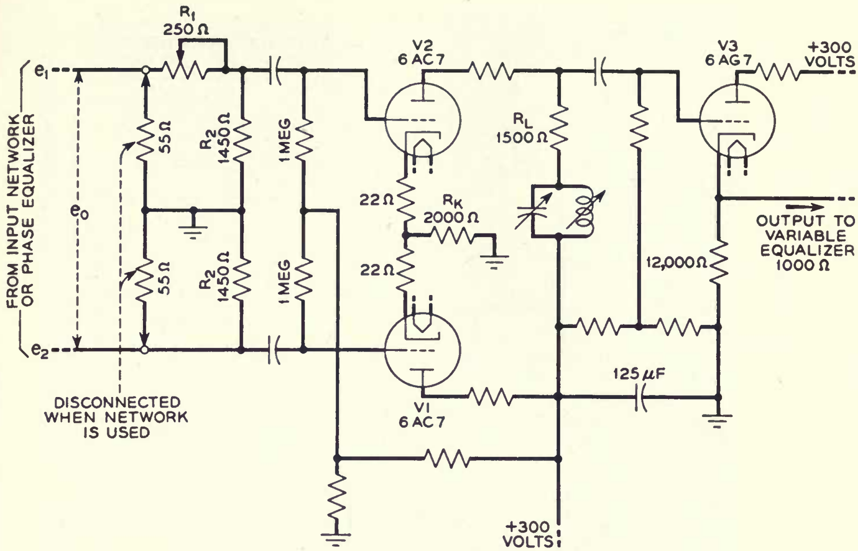


Fig. 6. Video repeater input amplifier—simplified schematic.

The output amplifier shown schematically in Fig. 7 provides 30 db of gain to the signal after it has been equalized and normally operates to furnish a 2-v peak-to-peak signal to the following cable section. Through the use of a network similar to that discussed in connection with the input amplifier a pre-equalized signal may be impressed on the following cable section with an attendant improvement in signal-to-noise performance. Balanced or unbalanced resistive terminations are also available if desired.

The physical arrangement of a video repeater is shown in Fig. 8. In this case a single repeater, cabinet-mounted for semipermanent use, is shown. In the central office three such repeaters are mounted on a standard 11-ft relay rack. A central office installation is shown in Fig. 9.

The Transmitting Terminal. Two versions of the video transmitting terminal are shown in Figs. 10a and 10b. The most commonly employed arrangement is given in Fig. 10a and consists essentially of a video repeating coil which permits coupling the usual 75-ohm unbalanced studio equipment to the balanced telephone cable, and a predistorting network which is employed when abnormally long cable circuits are involved. The repeating coil has a substantially flat transmission characteristic over the video band with the 3-db loss points at 30 cycles/sec and at about 8 mc. The physical arrangement of this type of video transmitting terminal is shown in Fig. 11.

In a few instances the first section of cable may be of considerable length. Here an amplifier may be employed as indicated in Fig. 10b. This amplifier is identical with the output type employed in the video repeater just described. The use of this alternative transmitting terminal permits the first cable section to extend to 3½ miles in length as compared with a maximum length of 1.7 miles when a repeating-coil type of transmitting terminal is employed.

Receiving Terminal. In Figs. 12a and 12b two alternative receiving terminal arrangements are shown, the choice

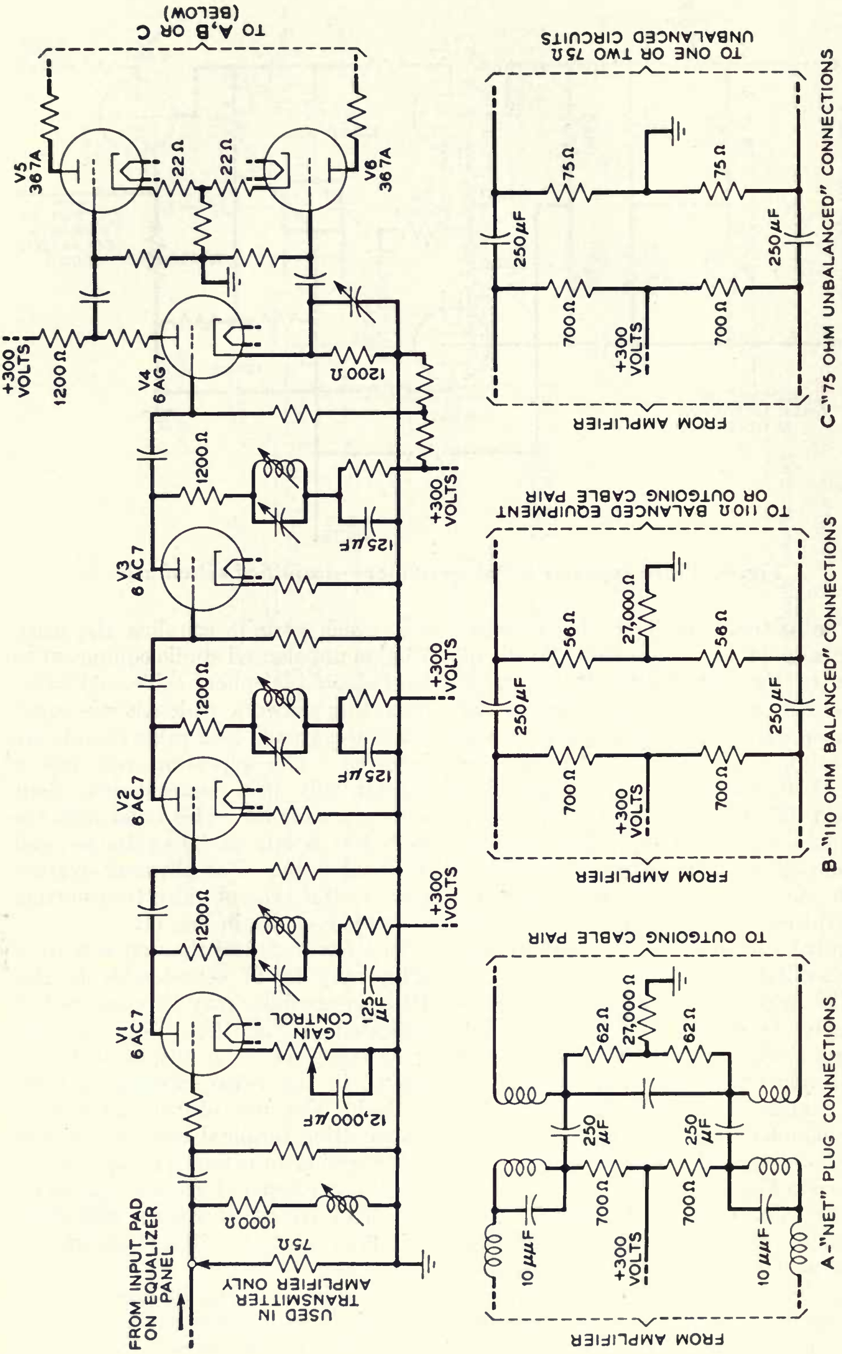


Fig. 7. Video repeater output amplifier—simplified schematic.

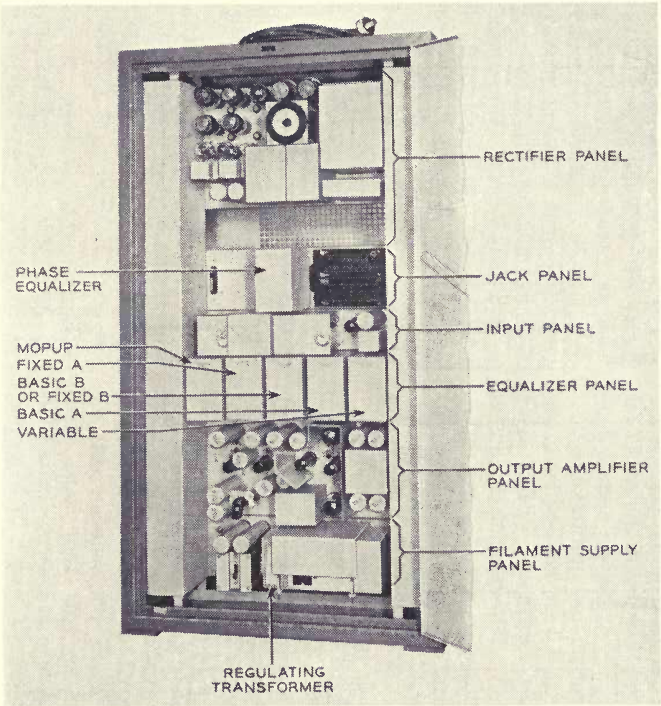


Fig. 8. Video repeater, cabinet-mounted.

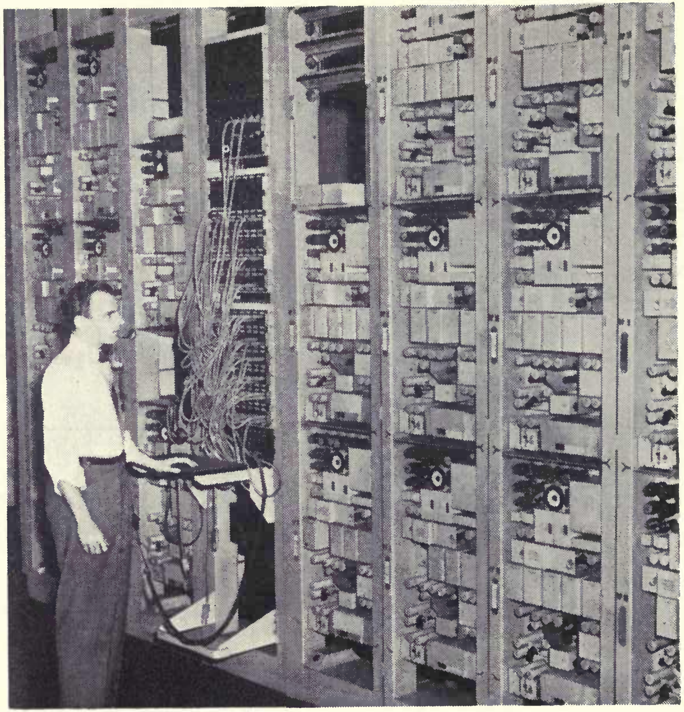


Fig. 9. Installation of video repeaters in a telephone office.

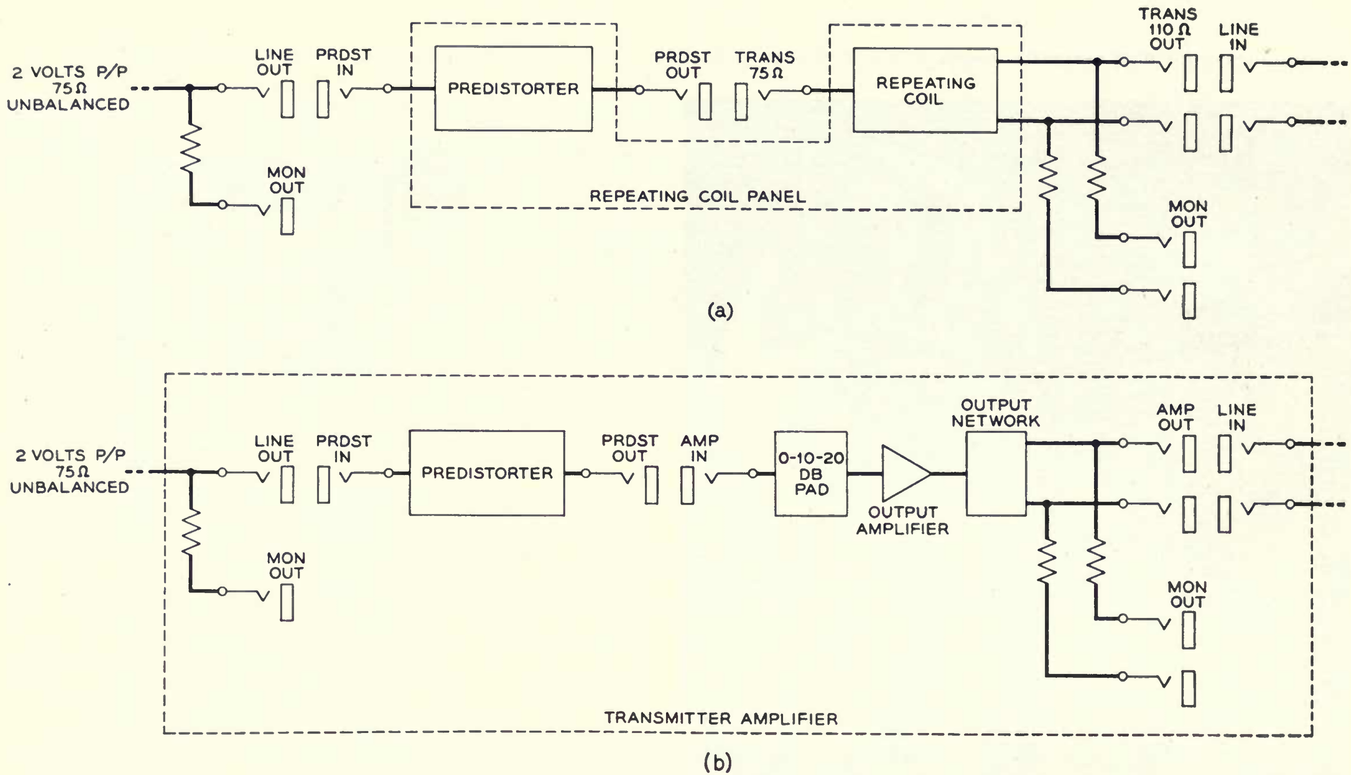


Fig. 10. Video transmitting terminals—block schematics.
(a) For cable sections up to 1.7 miles long; (b) For cable sections up to 3½ miles long.

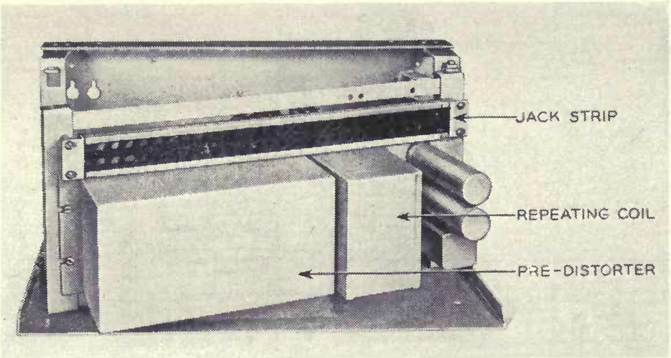


Fig. 11. Video transmitting terminal in wall-mounted bracket.

being primarily dependent on the loss of the final cable section. For shorter lengths of cable where the loss at 4 mc does not exceed 27 db, the arrangement of Fig. 12a is commonly employed. This terminal consists of a video repeating coil, a restorer network if required, and clamper amplifier. The clamper amplifier whose operation has been discussed elsewhere,[1] affords protection against low-frequency noise interference, as well as minimizing the transmission distortion introduced at very low frequencies by the repeating coil. The clamper amplifier here employed has a gain of 18 db and will furnish a 2-v peak-to-peak video signal into a 75-ohm impedance for use by the customer. It affords a 31-db reduction of 60-cycle interference.

If the final section of cable is greater than about 1½ miles, the receiving terminal arrangement shown in Fig. 12b is used. Here the basic components of the video repeater are employed and, if required, in addition a clamper amplifier is included as shown.

System Performance

The objective in the transmission and equipment design of the video system just described is to provide adequate transmission of video signals in local exchange areas with a minimum of cost. The final cost of such service is dependent only in part on the initial equipment and cable investment. The installation and maintenance charges contribute substantially to the over-all system cost. The ability to provide prompt and straightforward interconnections in the local area, regardless of the specific peculiarities of the particular situation, is a basic requirement of such system design.

The following two circuit examples are given to illustrate the application of these video components to the specific conditions encountered.

In Fig. 13 the transmission performance of a 2.78-mile circuit containing one repeater and simple terminals is given.

In Fig. 14 a longer and more complex example is presented. Here the total circuit length is 11.72 miles and is further complicated by the fact that one of the cable sections is 5 miles in length. This extreme condition is met here by transmitting the signal at a somewhat higher-than-normal amplitude over this section and also by operating the following repeater at somewhat increased gain. In this instance the noise conditions were such that this procedure was allowable. A mop-up equalizer is also employed to reduce the residual trans-

[1] S. Doba, Jr., and J. W. Rieke, "Clampers in video transmission," *AIEE Trans.*, vol. 69, Pt. 1, pp. 477–487, 1950.

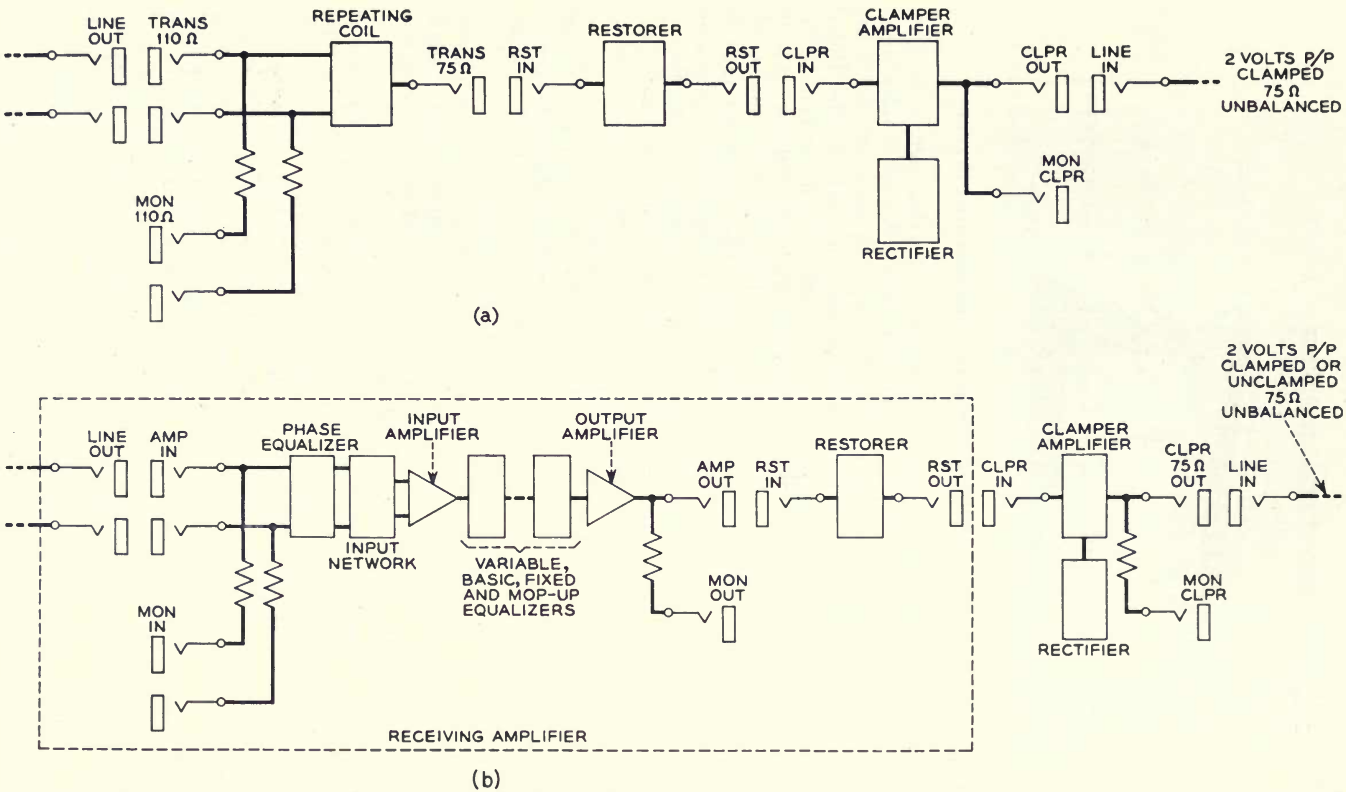
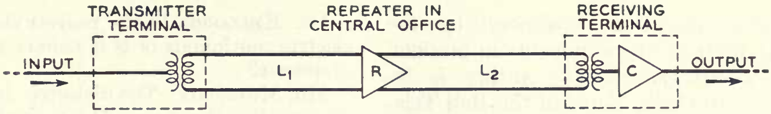


Fig. 12. Video receiving terminals—block schematics.
(a) For shorter lengths of cable; (b) For cable, final section of which is greater than 1½ miles long.



C = CLAMPER AMPLIFIER

CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	1.11	20
TOTAL	2.78	50

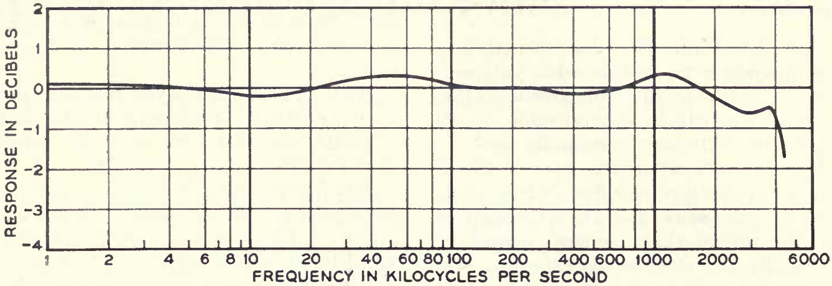
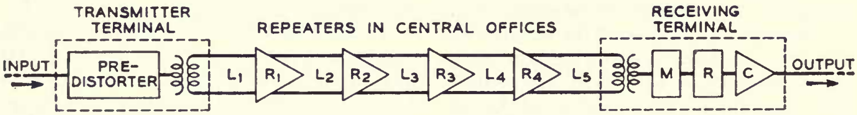


Fig. 13. Video circuit application—2.78-mile circuit.



M = MOPUP EQUALIZER
R = RESTORER
C = CLAMPER AMPLIFIER

CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	5.0	90
L_3	1.33	24
L_4	2.39	43
L_5	1.33	24
TOTAL	11.72	211

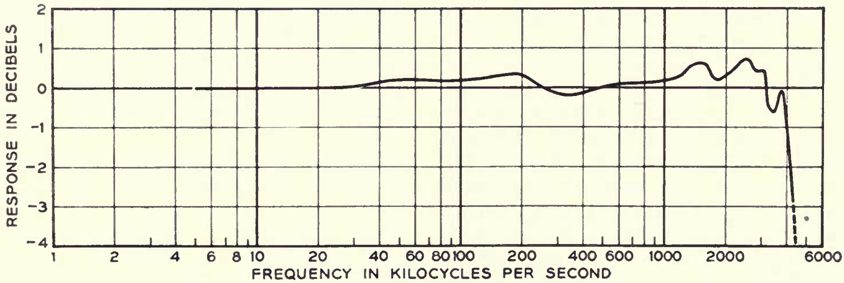


Fig. 14. Video circuit application—11.72-mile circuit.

mission distortion occasioned by the large number of components in tandem.

Acknowledgment. The author is indebted to C. N. Nebel of the Bell Telephone Laboratories for the illustrations used, as well as for the performance data for the two local video circuits discussed.

Discussion

E. W. Kellogg: How does the attenuation characteristic of the cable you were showing in this picture compare with that of your long-distance coaxial cable, and to what is the difference principally due?

Mr. Morrison: In the case of the 16 PSV (polyethylene shielded video) cable, the characteristics are almost identical. As to attenuation versus frequency: essentially, the attenuation rises almost as the square root of the frequency in all these cables where we have no high dielectric loss in the region we are talking about. Now, in the case of the coaxial cable, we have polyethylene dielectric and here we have the same, so we do have the same form of characteristic. And as to the amount of attenuation, it depends upon the copper. In the case of the coaxial, we are able to put more copper in the same size of tube, if you will. The attenuation is lower per mile. The unbalanced characteristic of the coaxial, however, does not permit its use for video transmission over very long distances. The coaxial is not well shielded for low-frequency power interference. It has a steel tape, to be sure, as well as copper; but it is not adequate for television transmission. We are able to transmit video frequencies on balanced conductors in these places where we have high levels of interference; and that is generally the case in any metropolitan area where these cables are run. So, in the coaxial we limit the lower frequency of transmission. On the present LI system we limit it to 60 kc. For television we limit it to about 200 kc. The top frequencies can be made anything if you are willing to put in enough gain and narrow the repeater spacings. The wider the band, the closer the spacings for the amplifier.

Dr. Kellogg: Is the polyethylene dielectric continuous or is it merely a series of spacers?

Mr. Morrison: The dielectric does not occupy all of the space. It is not solid. In the coaxial system we use beads, at approximately 1-in. spacing, little discs of polyethylene; and in the case of this video cable which you saw, we used string spirally wound around it and tape over that, so that a good percentage of the volume is air. That is just a matter of handling, and of course the material itself costs money.

H. J. Schlafly: Do you find that there are any other advantages of the longitudinally shielded PSV over the spirally shielded PSV?

Mr. Morrison: It is just a matter of the shielding that we obtain. Whereas we might get 120 db on one type as a reference number, we might get 20 db more on the longitudinally shielded conductor. It is just a matter of making a good tight copper shield around the conductor. The present manufacture is longitudinally seamed plus a winding as you saw in the second figure—a spiral tape of copper. It is shielding to external fields. That is all we gain by it.

E. A. Hungerford, Jr.: I was wondering if you could tell us anything about the possible demand for r-f distribution of television signals to advertising agencies and so on in New York City where you could get away from going through the air. Has the company had a requirement for that yet?

Mr. Morrison: There are always a certain number of requirements for experimental purposes that come in at the front or the back door. All though this, people are interested in point-to-point connections of television. There has been no real rush to connect up the city with a form of entertainment like Muzak in sound [distribution]. However, it is certainly within the realm of possibility, I believe; and for certain commercial and industrial purposes, the ability to connect up a video facility as you would connect up a telephone may prove to be rather attractive. But so far there is no commercial application of that sort of thing, none at least with which I am familiar.

A Professional Magnetic-Recording System for Use With 35-, 17½- and 16-Mm Films

By G. R. Crane, J. G. Frayne and E. W. Templin

This paper describes a portable magnetic-recording system for producing high-quality sound track in synchronism with pictures. The system has been designed to enable magnetic recording to conform with standard motion picture studio operating practices. A number of features such as high-speed rewind, interlocked-switching facilities, one basic type of amplifier and the use of miniature tubes throughout have been incorporated in the system.

THE MAGNETIC-RECORDING SYSTEM described in this paper is an evolutionary development of the application of magnetic-recording techniques for motion picture purposes. In previous papers presented before the Society,[1,2] complete descriptions have been given of the various supplemental magnetic-recording facilities which have been made available to the motion picture industry by Western Electric Company and the Westrex Corporation. The widespread use of these modified photographic recorders has provided an unusual opportunity to evaluate the performance under actual field conditions of the various circuits and mechanical devices incorporated in these modifications. In the design, therefore, of this completely new magnetic-recording system, those elements have been retained that have proved to be of definite value, while others that have proved superfluous have been eliminated.

It was stipulated that the new magnetic-recording system should be capable of being operated with any of the known motor systems commonly employed in the motion picture industry. These include single-phase and three-phase synchronous, a-c and d-c interlock, as well as multiduty operation.[3] The motor-control circuits of the recorder should be arranged so that in order to change from any one motor to another, it is only necessary to disconnect and remove the motor, replace it with the other type and reconnect it with a minimum of effort.

Before establishing a suitable sound-track position for this system, it was decided to adhere to what may become an industry-wide accepted standard. To this end, there has been active cooperation with the Motion Picture Research Council and the Magnetic Subcommittee of the SMPTE to try to

Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y., by G. R. Crane, J. G. Frayne and E. W. Templin, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

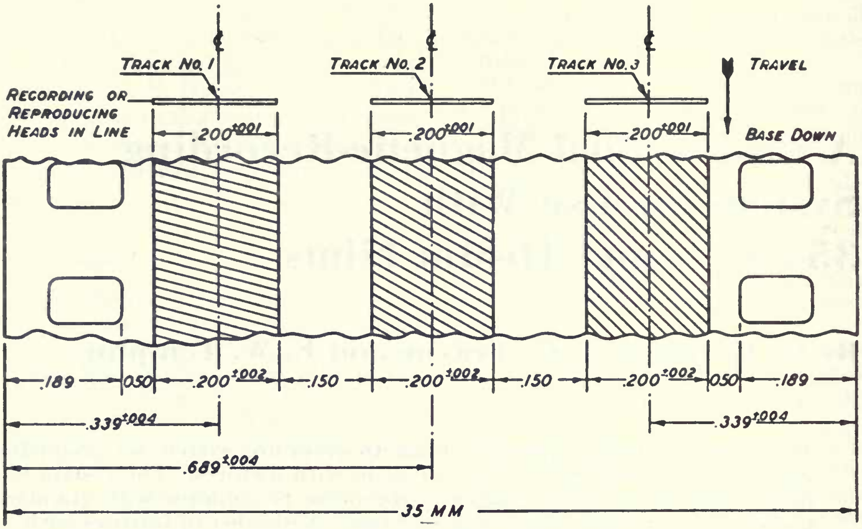


Fig. 1. Proposed magnetic film-track standards.

establish a single- and multiple-track standard for 35-, 17½- and 16-mm films. Unfortunately, the proposals of both of these organizations have not yet reached the stage of complete standardization, but the response of the great majority of equipment manufacturers and recording studios has been so favorable that it was decided to proceed on the assumption that they would eventually be accepted as standard.

The American Standards Association and the Research Council track proposal is shown in Fig. 1. It provides for three 200-mil tracks, with a separation of 150 mils between tracks and a 50-mil separation between outer tracks and sprocket holes. Track No. 1 on the left of the figure becomes the normal single track, and it will be noted that it is the so-called negative sound-track position. It differs from the original track location previously described in that it has been moved in from the 136-mil separation from the sprocket-hole side to the present 50 mils. This was done to permit the later development of multitrack recording in accordance with Fig. 1. It should be noted that although the recorder described below is designed to meet the new proposed track standard, provisions are incorporated for restoring the older track location when desired.

The situation with regard to 17½-mm film track standards is not as clear as with 35-mm film track. The original proposal was to record down the slit edge of this film. This would correspond to a positive sound-track position for this film. A later proposal called for the 17½-mm track to be in an identical position with that of the 35-mm film. In the recorder described below, provision has been made to record the 17½-mm track at either of these positions, and experience alone can tell which is more likely to be adopted on an industry-wide basis.

The track position for 16-mm film has been set at 6 mils from the unperforated edge and no request has been made so far for any variation from this position. In all three cases, the track width is 200 mils and the same recording head is used for all three positions.

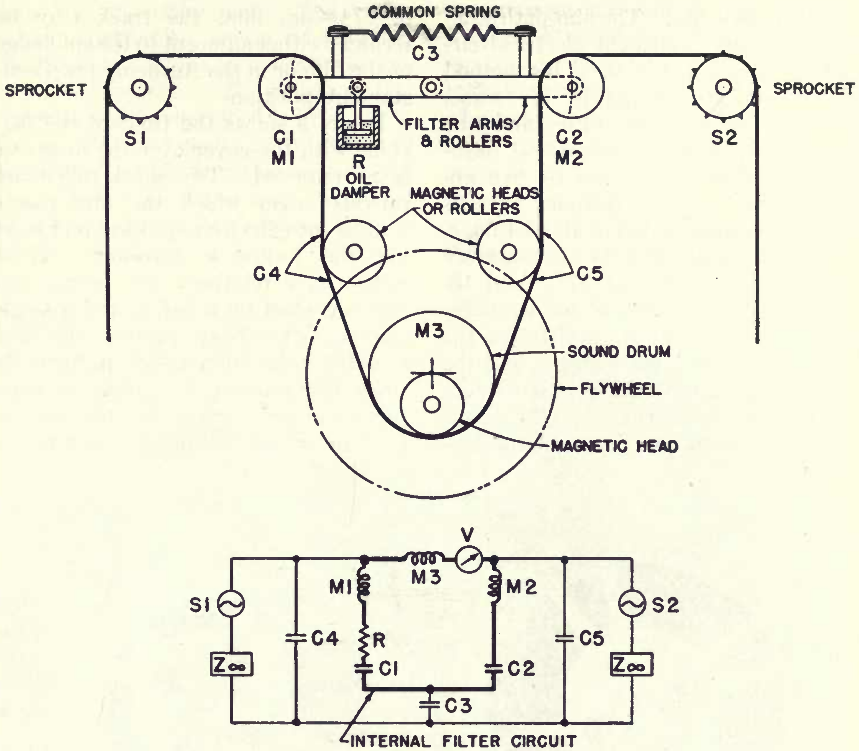


Fig. 2. Film-drive schematic.

It was decided that provision for high-speed film runback should be available in this system. This was considered a necessity in the foreign field and a desirable accessory in the domestic field. An actual runback speed of 3× has been provided in the system described in this paper. As will be seen later, this is accomplished without unthreading the film in the recorder.

Recorder

The recording machine has been designed primarily for portable use as a production recorder for magnetic sound in synchronism with a motion picture. The machine and its control features are readily adaptable to any of the current types of motor-drive systems including interlock, multiduty and synchronous, either 1 ϕ, 115 v or 3 ϕ, 220 v. In addition, it may be readily equipped for operation with 35-, 17½- or 16-mm film which changes only a few parts of the recorder, such as rollers, sprockets and reel shafts.

Recorder Film Path

The film drive is of the Davis type, which was discussed in an earlier paper published in the JOURNAL,[4] and consists of two 16-tooth sprockets with a symmetrical, tensioned path between them, which includes two filter rollers and an impedance drum within which is located the record head. The path also includes a slight wrap around a monitor magnetic head beyond the drum, and a roller which may be replaced by an optional erase head just

ahead of the drum. The film-path schematic and its equivalent electrical circuit are shown in Fig. 2. This method of mechanical filtering is, of course, in effect a low-pass filter and the damping is provided by an oil dashpot connected to one arm to give approximately critical damping at its natural resonant period of about 1.6 sec.

The film path and its elements are essentially the same for 17½- and 16-mm film. In the case of the narrower film widths, the lateral position of the magnetic heads is not changed and the roller flanges are placed so that the film is properly registered with the heads for correct track position. In the case of 17½-mm film, the track may be recorded either adjacent to the split edge of the film or in the Academy proposed-standard position.

Figure 3 shows the front of the machine with the cover over the magnetic heads removed. Two shock rollers are provided over which the film passes coming into the feed sprocket and leaving the holdback sprocket. These rollers have relatively low inertia and are controlled by a spring and a single oil dashpot. They protect the film sprocket holes from abuse, particularly when the machine is started or when there is any abnormal operation such as jerks or erratic motion imparted to the

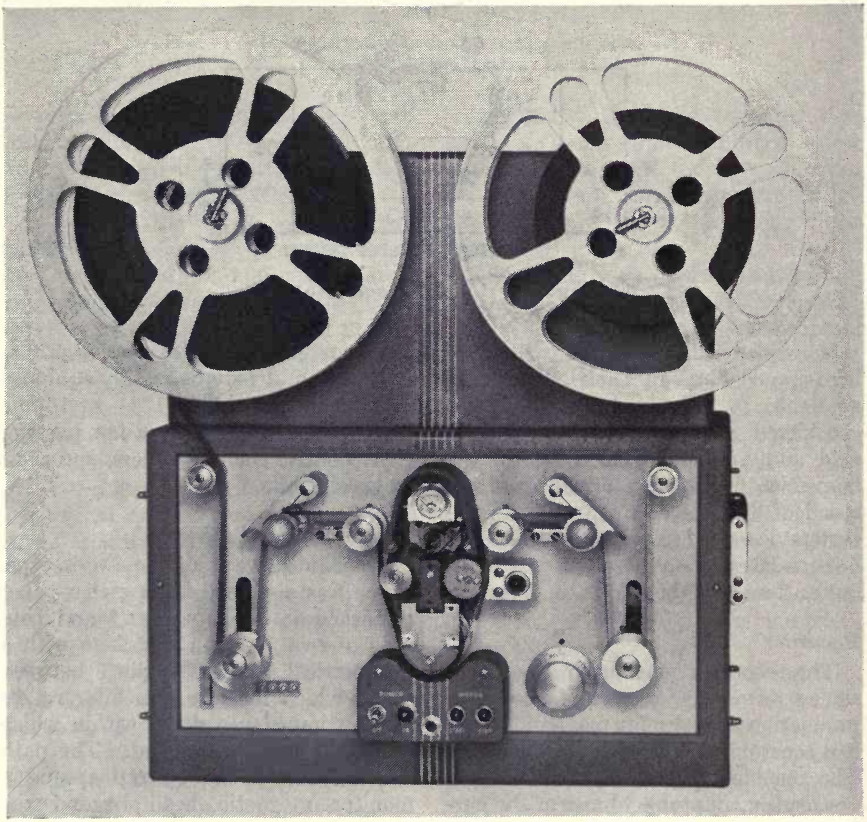


Fig. 3. Front view of RA-1467 Recorder with cover of head assembly removed.

film by imperfect reels. The right-hand shock roller serves also as an "antibuckle" device or indicator of loss of take-up tension. The details of this function will be described later.

The film sprockets have relatively large teeth which fit rather closely into the sprocket holes and take advantage of the low-shrinkage characteristics of the new acetate-base film. The tooth clearance in the hole is still sufficient to permit satisfactory operation with moderately shrunk film as high as 0.6%, but the clearance is small enough to eliminate most of the so-called crossover effect caused by the changing film tensions on the two sides of the sprocket causing the sprocket to act alternately as a feed and holdback sprocket. Both sprockets have flanges as an aid to rapid

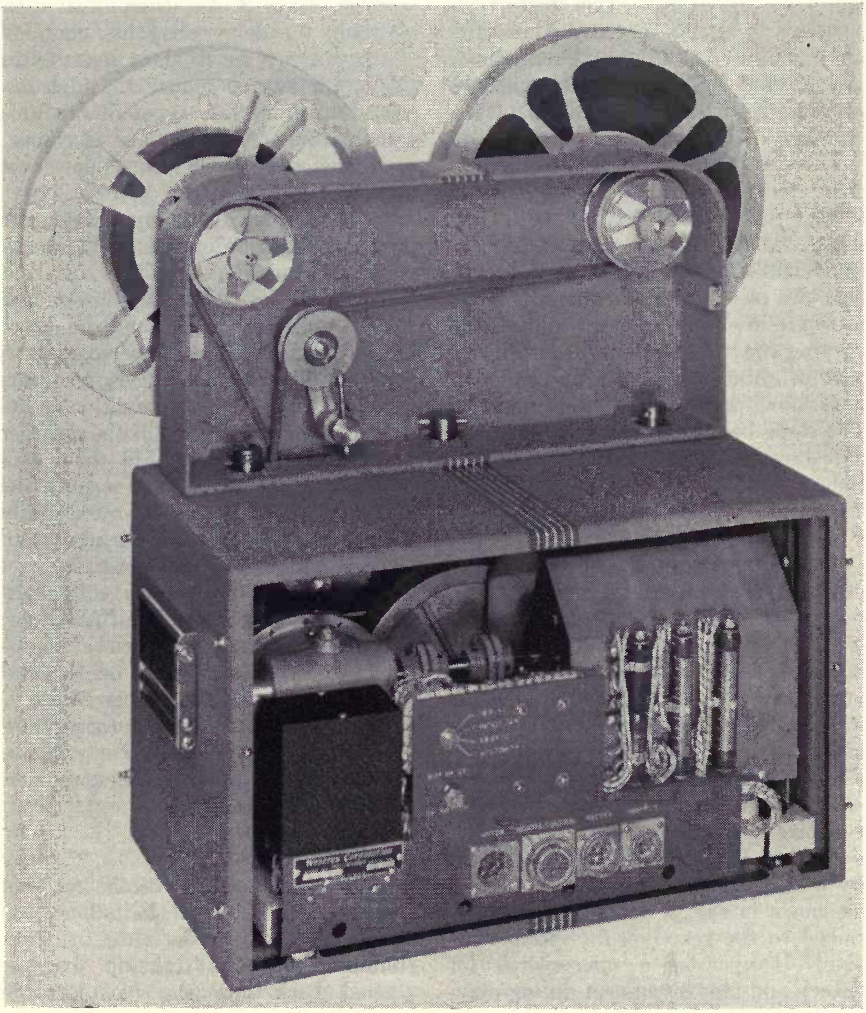


Fig. 4. Rear view of RA-1467 Recorder.

threading and this has permitted the use of a simple film shoe instead of the usual sprocket pad-roller assembly. This shoe is adjusted so that it clears the film surface during normal operation. It serves only as a guard for such conditions as starting and stopping the equipment. Each sprocket also has a knob by which the machine may be turned over when the selector knob is in the "Neutral" position. Since the motor is disengaged, this feature is particularly useful in cases where the machine is used as a dubbing reproducer and a start mark must be registered without disturbing the position of the interlock motor.

The film passes in and out of the machine to reels located above, with a single, round belt driving both reel shafts, which may be seen in Fig. 4. Convertible overrunning-clutch assemblies are provided to permit either reel to rotate in either direction to meet the varying practices with regard to direction of rotation of feed and take-up reels now prevalent in the industry. The same belt may be used with alternate crossed paths to change the rotation.

Recorder Controls

The motor is controlled by a d-c relay of the mechanical-latch type with push buttons for start and stop. This system has the double advantage of having no power in the relay during operation of the machine, thereby simplifying the magnetic shielding problem and providing a convenient method for controlling the recorder remotely with momentary-contact switches carrying only relay-coil current.

The machine functions are controlled by a single selector knob on the front, as shown in Fig. 3. It is mechanically linked to the gear box for speed selection. It operates a microswitch for speech and bias disconnect during playback and rewind, and also disables the antibuckle device during rewind. Erase facilities are controlled in a similar manner if used.

The shock roller which is used for indication of take-up failure occupies the same position at rest and at take-up failure; therefore, the operating circuit is not energized until 3 sec after start. A time-delay relay across the motor circuit performs this function as well as operating the relay to transfer the recordist's monitor from direct to film monitor after 3 sec from start. In addition, the delay relay has contacts closing after 1 sec to short resistors in the motor line to reduce the high acceleration of certain types of synchronous motors. All relays are, of course, reset instantaneously when power is removed.

In the event of take-up failure, the motor is lifted from the line and the main transmission circuit is disabled which removes the signal from the mixer's volume indicator and the direct monitor line. Since the recorder is stopped, film monitoring is also terminated. The buckle condition is restored only by operation of the recorder power switch to "Off," but the motor is not reconnected to the line until the motor "Start" button is operated again.

To provide the proper correlation of the synchronous-motor starting resistors, the time-delay relay voltage requirements, and other circuit functions, a four-position switch with a screwdriver-slot control appears on the rear panel of the recorder. This switch is set to the indicated position for any one of the various types of motor systems, thereby making all of the necessary circuit changes.

Recorder Structure

The upper assembly of the recorder containing the two reel shafts is removable from the recorder case by three thumbscrews. The take-up belt is pushed back into the recorder and covered with a sliding cover. Space is provided in the control unit for contain-

ing the reel assembly when the system is to be transported. The recorder case has a removable rear cover for access to the motor-starting resistors and other components, and contains a recessed opening through which all of the cords may be inserted into the recorder receptacles. A front cover with a transparent window is used primarily for a dust cover during stand-by or for shipment. It is also useful in those cases where the recorder is to be operated near the action, thereby requiring further reduction of recorder noise and that caused by the film engagement on the sprockets. An accessory magazine is also available for completely enclosing the two film reels for further reduction of noise caused by film scuffing on reel flanges. This magazine is demountable and has transparent doors for visibility.

Mechanical Drive

As previously mentioned, various types of motors may be accommodated and the one selected is directly coupled through a torsionally rigid, flexible coupling to a gear box.

Between the gear-box output shaft and a cross shaft, interchangeable sets of 90° helical-change gears are used to accommodate all currently used motor speeds from 1000 to 1800 rpm for either 35-mm or 16-mm film speeds. The cross shaft drives each of the two sprocket shafts through similar 90° helical gears. Each of these three sets of gears has a nylon plastic gear driven from a steel gear which gives quiet and smooth operation. Nylon was chosen as the nonmetallic material since it has unusual properties suitable to this application. It is capable of running with virtually no lubrication and performs very well over long periods of time with a minimum of lubrication provided by a drop or two of a special oil which clings to the tooth surfaces with high tenacity. The material is extremely tough and accepts considerable abuse in shock loading without damage.

The gear box accomplishes a 3:1 speed change by means of planetary gears and the ratio change is accomplished by a spring-loaded control rod protruding from the center of the driven shaft.

The take-up clutches associated with each reel shaft contain overrunning clutches as well as a frictional drag to the frame of the machine, so that no attention need be given to the take-up performance regardless of the direction or speed of the recorder. The take-up clutch provides the proper film take-up tension on the reel which requires it, and a second small clutch places a light drag on the feed-reel shaft to insure stable operation.

The impedance drum, the two sprocket-shaft assemblies and the pad-roller assemblies have their ball bearings contained in tubular subassemblies so that their lateral position may be easily adjusted and locked by means of set screws. All rollers have their shafts arranged so that they may be likewise adjusted laterally. These facilities permit changes and alignment adjustments in film-path components to be readily made with a minimum of effort. Until track positions are more universally standardized and accepted, this feature may be useful.

The head assembly containing the two magnetic heads, or three in the case of the erase option, may be removed as a complete unit and replaced on dowel pins without disturbing any of the head adjustments relative to the impedance drum. The wiring between the magnetic heads and the recorder is terminated through a small symmetrical seven-pin plug arranged to permit a 180° turnover. This reverses record and moniter connections so that the monitor head may be used in the rare event of failure at the record-head position or the record head may be used for high-quality reproduction as in the case of transfer machines or high-quality playback. The record and monitor

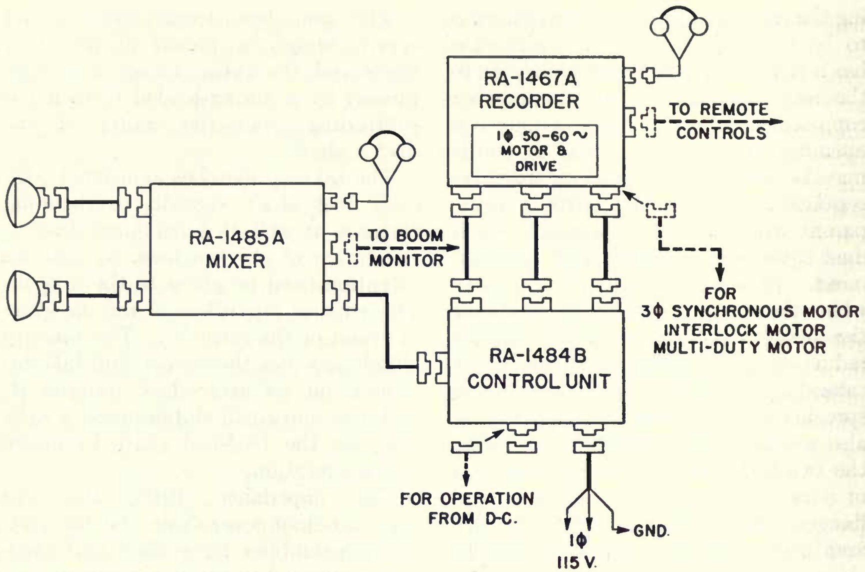


Fig. 5. System block schematic.

heads have mountings equipped with vernier-screw adjustments for setting azimuth quickly and accurately, and the solidly mounted record head has a vernier adjustment for its position relative to the impedance drum and the film. The head curvature lying within the film curvature determined by the impedance drum insures excellent contact with the magnetic coating and its position is such as to insure a long period of service without requiring any readjustment for wear compensations.

Transmission System

An over-all block schematic of the system is shown in Fig. 5. The three basic units are shown: the Recorder, the Mixer and the Control Unit. The control unit is normally associated closely with the recorder and connected to it by two 10-ft interconnecting cables. The motor cable also connects directly between the recorder and control unit when a 115-v, 1-ϕ drive motor is used. Only one interconnecting cable is required between the mixer and the control unit. The separation between these units may be 50, 100 or 150 ft with no special provisions required for normal variations in power-supply voltage and voltage drop in the interconnecting cable. An additional cable from recorder to studio facilities may be used to provide motor start-stop controls, speed signal and footage-counter control at remote points.

The transmission system is built up of combinations of three basic types of electronic subassembly components: an amplifier, an oscillator and a power supply. This method of building up the system from a minimum number of standardized types of subassemblies has several advantages, including economy of manufacture, simplicity of maintenance and a minimum investment in studio plant and location spares.

Amplifier

Only one type of amplifier is used throughout the recording system. A total of four are used in the system, one each for the two microphone preampli-

fiers, one for the main recording amplifier and one for film monitor. Only one type of vacuum tube is used in all the amplifier applications—the G.E. 12AY7 miniature twin triode. The special performance requirements for the particular amplifier applications are all accommodated by a series of plug-in units which make connections to internal circuits of the amplifier.

With suitably filtered power supply for plates and heaters and with a reasonable amount of selection of tubes for the input stage, a noise level of approximately −125 dbm, referred to the amplifier input, may be obtained. This permits a signal-to-noise ratio of approximately 55 db for normal dialogue pickup from a W.E. RA–1142 Microphone.

The amplifier will carry an output power level of +22 dbm for 1% distortion which provides a comfortable margin over that required for both recording and monitoring applications.

The power requirements are 10 ma (milliamperes) at 275 v d-c and 0.3 amp at 12 v. A d-c or rectified a-c heater supply is recommended for all low-level applications.

Bias Oscillator

The oscillator is of the L-C tuned-grid type, operating at 60 kc and employing one 12AU7 twin triode operating in push-pull. The total distortion appearing at the oscillator output terminals is less than 1/10 of 1%. The oscillator will deliver at least 35 ma at 60 kc into the record head. The power requirements are 6 ma at 275 v d-c and 0.15 amp at 12 v a-c or d-c.

Power Supply

The power supply provides line-and-load-regulated plate current and unregulated heater current for the entire system. It requires 1 amp from a 50- or 60-cycle 115-v power source.

The circuit includes a 3-stage d-c amplifier and a series regulating tube. Regulation over a line-voltage range of ±10% and a load range of 0 to 55 ma is obtained with a maximum of not more than 0.5 v variation in output. The total power-supply ripple is approximately 0.5 mv or less over the complete load range. The a-c impedance of the output is also held to a very low value, thus simplifying the decoupling requirements between stages of an individual amplifier as well as between high- and low-level amplifiers. The output voltage is adjustable over a range of 255 to 300 v but is normally intended to be set to 275 v.

A bridge-type selenium-cell rectifier is used to provide 12 v d-c for vacuum-tube heater and relay control circuits. This supply is biased 20 v above ground which makes the vacuum tubes in low-level stages less sensitive to residual power-frequency ripple and simplifies the filtering requirements. This supply provides 1.8 amp at 12 v with a ripple less than 1 v. For a ±10% variation in power-supply voltage and for mixer cable lengths up to more than 100 ft, the voltage at the heaters is within safe operating limits without special regulating or current-limiting provisions.

Mixer

The mixer is a complete speech-input equipment having two microphone inputs and supplying signal directly to the recording head, direct-monitor lines and volume indicator. Figure 6 is a view of the mixer.

Three of the basic amplifiers previously described are used in the mixer, two as microphone preamplifiers and one as the recording amplifier.

For the preamplifier application, the plug-in unit inserts variable dialogue equalization and low-frequency pre-equalization. The dialogue-equalizer characteristic is selected by a control knob on the top of the plug-in unit. The response curves are shown in Fig. 7. One position provides the normal flat amplifier characteristic; the other two provide, respectively, 8- or 12-db droop

at 100 c(cyles per sec). These characteristics follow the conventional ones that have been used for many years in Hollywood studios. Below the useful dialogue range they maintain sufficient loss so that a high-pass filter is not normally required. This is particularly the case since the low-frequency difficulties in photographic recording attributable to noise-reduction and peak-limiting operations are inherently absent.

The low-frequency pre- and post-equalization used in the system takes advantage of the energy-distribution characteristic of speech and music[5] to increase the margin between signal and residual-hum components in the reproducing or monitor system. As shown in Fig. 7, the pre-equalization amounts to a 2½-db rise at 50 c.

The design of the equalizers is such that the gain in the region of 1000 c is essentially unchanged for all settings of the dialogue equalizer and with the low-frequency pre-equalizer in or out of circuit.

The plug-in unit also contains resistive elements which introduce attenuation in the amplifier circuits terminating therein. The gain of each stage is thereby carefully established at the value giving the best possible balance between signal-to-noise and margin-from-overload, based on the sensitivity of the microphone and the range of input level to be accommodated. The midfrequency gain of the amplifier as

Fig. 6. View of RA-1485-A Mixer.

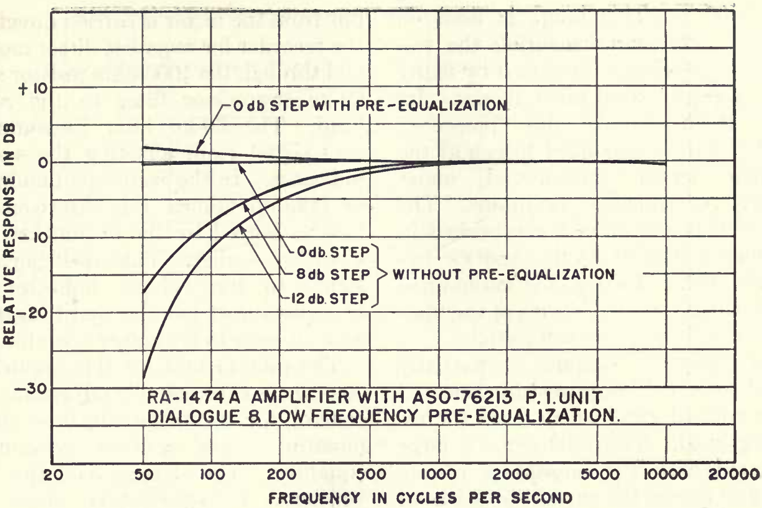


Fig. 7. Preamplifier gain-frequency characteristics.

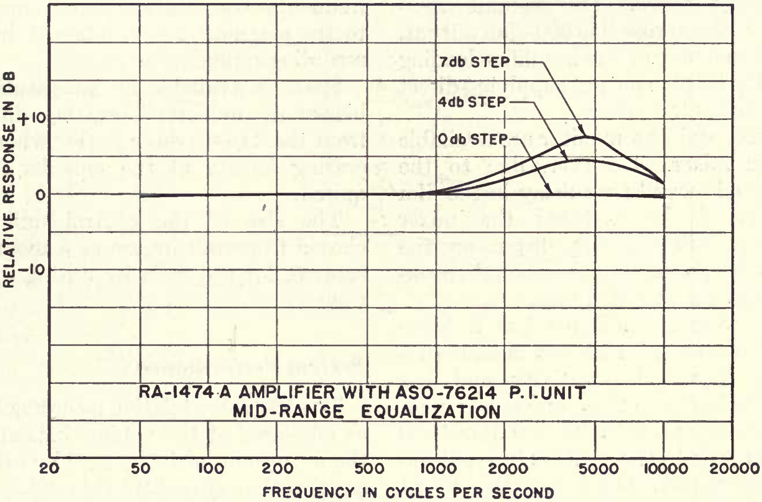


Fig. 8. Recording-amplifier gain-frequency characteristics.

established by the plug-in unit is 53 db.

The preamplifiers are followed by separate microphone cutoff keys, mixer pots, a combining network and a gain switch having three 10-db steps.

Following this is the recording amplifier with its input connected for unbalanced, 600-ohm, terminated operation. The plug-in unit in this application provides two steps of midrange equalization in addition to the flat characteristic, a choice of the three conditions being selected by the control knob in the top. As shown in Fig. 8, this equalization consists of a rather broad peak of either 4 or 7 db centered

near 5000 c. This boost is used on dialogue only, supplementing the rise in this same region introduced by many of the regularly used microphones. Its result is to improve the "presence" quality of the reproduced speech at the listening levels encountered under theater reproducing conditions. The gain of this amplifier is established in the plug-in unit at 58 db, and for frequencies below 1000 c it is maintained at this value for all positions of the mid-range-equalization control switch.

The 600-ohm output is partially loaded by a 1000-ohm resistor (located in the control unit) which feeds the recording head. The 1000 ohms is large compared with the impedance of the head and causes the current in the head to be substantially independent of the head impedance throughout the audible frequency range. The volume indicator is also across this 600-ohm output. The remainder of the amplifier loading is on the 50-ohm output supplying direct monitor for the mixer.

Direct and film monitor are available in the mixer. However, due to the fractional-second time delay in the film monitor, it is expected the mixer operator will normally listen on the direct line, with only occasional checking from the recorded film.

The volume indicator has a high-speed movement and new design providing increased sensitivity and less bridging loss than those previously used. Its maximum sensitivity is 0 dbm for 0 db meter deflection and its internal impedance is such that it may be used at this setting under operating conditions.

Control Unit

The control unit contains miscellaneous components including the bias oscillator, film-monitor amplifier, power supply and interconnecting circuits between the mixer and the recorder. It also provides storage space for the film-reel assembly which mounts on the recorder during operations. The output from the mixer is carried directly to the recorder for recordist direct monitor and through the 1000-ohm resistor and a 60-kc suppressor filter to the record head. The 60-kc filter prevents the bias signal from affecting the volume indicator. In the event of a film buckle or take-up failure, this direct-monitor line is shorted by the antibuckle relay described earlier. This also shorts the signal to the volume indicator and recordist direct monitor and thus serves as a warning to the mixer operator.

The plug-in unit for this application contains a continuously adjustable gain control, for balancing film and direct-monitor levels, and a reproducing equalizer. The latter has the conventional 6-db-per-octave slope plus low-frequency postequalization complementary to the pre-equalizer, and high-frequency equalization complementary to the magnetic losses inherent in the recording-reproducing process.

Space is available for substituting a bias-erase oscillator operating directly from the 115-v power source when the erasing facility at the recorder is required.

The size of the control unit was chosen to permit its use as a mounting support for the recorder during operations.

System Performance

The 100%-modulation recording level, as measured at the volume indicator in the mixer unit, is determined by making a series of measurements of output level and per cent distortion at the reproducing-amplifier output for various values of recording level and bias current. A typical set of data for a particular recording head and film emulsion is shown in Fig. 9. Based on an allowable total harmonic distortion of 3%, it can be deduced from the curves that a 100% modulation recording level of ± 10 dbm, with a bias current of approximately 25 ma, is optimum. Lower

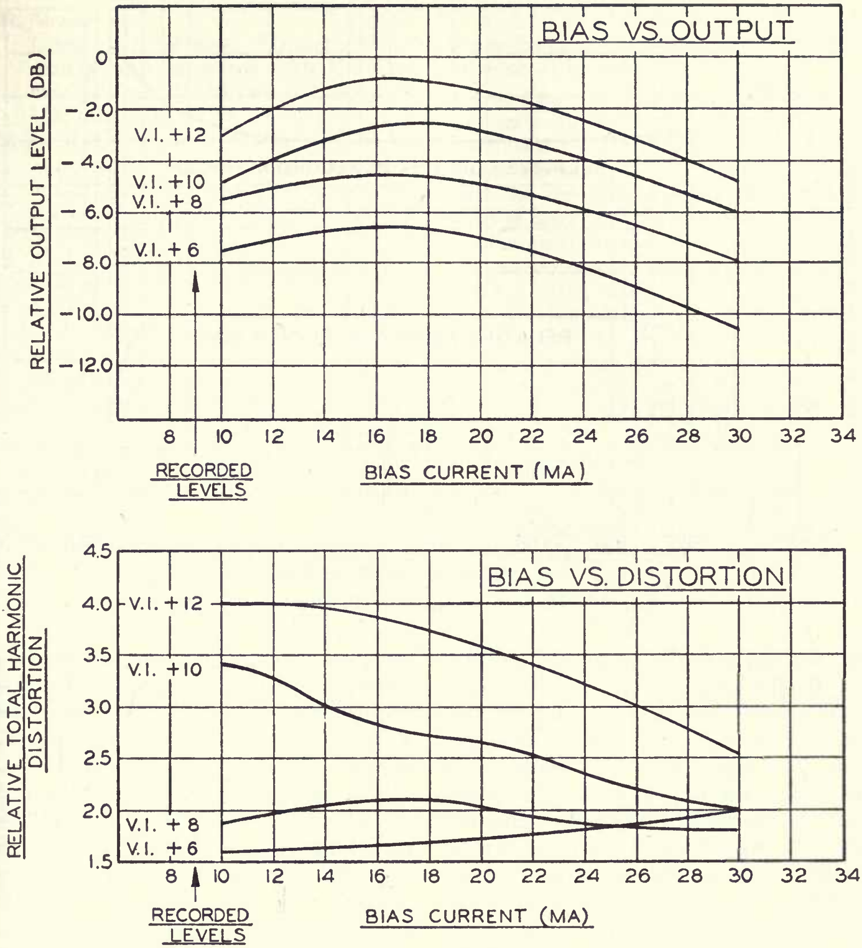


Fig. 9. Magnetic-recording characteristics.

recording levels give a lower reproducing level with corresponding decrease in signal-to-noise ratio. Higher recording levels require increased bias current for the permissible amount of distortion, with no appreciable increase in output level. For this optimum operating condition, a level of −4 dbm is available at the recorder on either direct or film monitor.

By means of the mixer pots and main gain control, a 60-db range of input level may be held to the 100% modulation level of the system. For any combination of mixer and gain settings, the carrying capacity will be limited by the film medium rather than by the transmission equipment.

The signal-to-noise ratio of the recording circuit as limited by the first stage of the preamplifier is approximately 55 db for normal dialogue.

The over-all record-reproduce film characteristic for 35- or 17½-mm films,

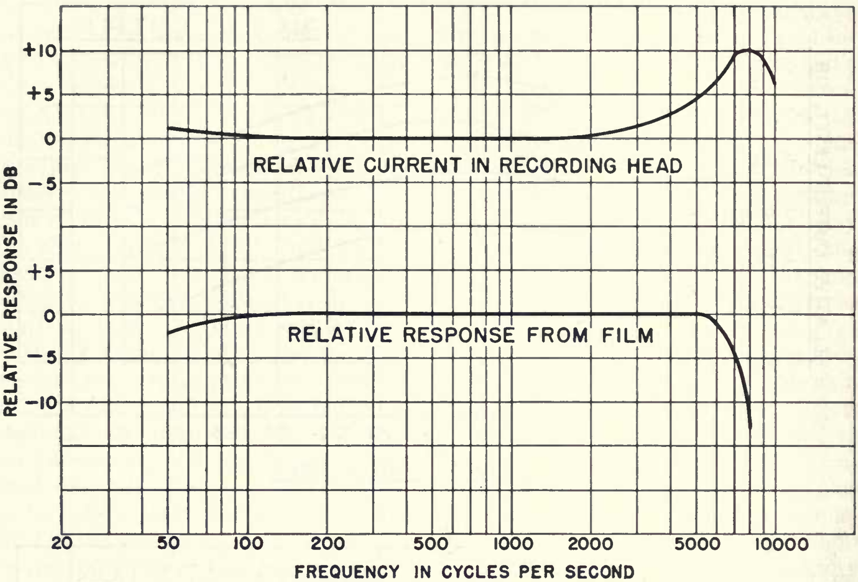


Fig. 10. 16-mm frequency characteristics.

for flat input to the mixer and, excluding the dialogue and midrange equalization, is essentially flat from 50 to 7000 c, which is more than ample for monitoring purposes. For high-quality re-recording, the flat response may be extended upward to 10,000 c by using the film-loss equalizers, normally a part of existing photographic-magnetic re-recorders. A signal-to-noise ratio from the reproduced film of approximately 55 db may be obtained. For special applications, this may be increased to 60 db or more as has been done in earlier photographic-magnetic equipment[1] by additional low- and high-frequency pre- and post-equalization.

Where high-frequency pre-equalization is to be utilized for this further increase in signal-to-noise ratio, an appreciable portion of it can be considered as precompensation for the magnetic and scanning losses inherent in the recording-reproducing process. These latter losses then introduce the compensating post-equalization to provide the flat over-all record-reproduce characteristic. Thus, if the high-frequency pre-equalization is held to that value required to precompensate for these losses, an electrical high-frequency post-equalizer is not required and flat response up to approximately 9000 c may be obtained. For 35-mm or 17½-mm film, this pre-emphasis has been obtained by a condenser-resistance combination shunted across the 1000-ohm resistance in the recording-head circuit.

For 16-mm film, with its inherently lower cutoff frequency, a series-tuned circuit is bridged across the resistor in series with the head to provide a high-frequency pre-equalization characteristic as shown in Fig. 10. A typical gain-frequency response from film recorded with this characteristic and reproduced on a high-quality re-recorder is also shown in Fig. 10. The response is substantially flat to approximately 6500 c, except for the low end which contains reproducing post-equalization to compensate for the low-end pre-equalization generally used in Western Electric magnetic recording systems.[1]

References

1. Lewis B. Browder, "Direct-positive variable-area recording with the light valve," *Jour. SMPE*, vol. 53, pp. 149–158, Aug. 1949.
2. G. R. Crane, J. G. Frayne and E. W. Templin, "Supplementary magnetic facilities for photographic sound systems," *Jour. SMPTE*, vol. 54, pp. 315–327, Mar. 1950.
3. A. L. Holcomb, "Motor systems for motion picture production," *Jour. SMPE*, vol. 42, pp. 9–33, Jan. 1944.
4. C. C. Davis, "An improved film-drive filter mechanism," *Jour. SMPE*, vol. 46, pp. 454–464, June 1946.
5. L. J. Sivian, H. K. Dunn and S. D. White, "Absolute amplitudes and spectra of certain musical instruments and orchestras," *J. Acous. Soc. Amer.*, vol. 2, p. 330, Jan. 1931.

Discussion

E. W. Kellogg: With regard to the Davis Drive mentioned in the paper, I don't know just what it is intended to cover by that name, or what features are to be credited to Mr. Davis. I wish to call attention to the fact that if, broadly, the filter system means a solid flywheel on the shaft of a drum, and compliance introduced between the driving sprockets and the drum by means of a flexibly mounted idler-roller, that system dates back to ancient history. It was shown in a Triergon patent filed in the United States in 1922. It was again shown in slightly more definite form in a patent to Poulsen and Petersen, under which an unsuccessful infringement suit was brought against RCA Mfg. Co. and Electrical Research Products, in the late 1930's. It is a very effective filter, and I think all fundamental patents on it have long since run out. The feature of connecting a dash-pot to the movable idler is described in a 1931 paper of mine, describing the first RCA magnetic-drive recorder and also in the corresponding patent, in which broad claims were allowed on damping. I think that we should, in attaching anyone's name to a filter system, make it clear that it does not comprise those broad features that I have just described. Perhaps you can enlighten us about the features that have been added in the way of refinements or improvements.

In the machine just described, what is the position of the recording or reproducing magnet in relation to the drum?

Dr. Frayne: In connection with Dr. Kellogg's question, all the data on the track width and location will be found in the published paper. I would say this, that the recording part of the magnetic head is placed as close to the drum as is mechanically feasible. Under those conditions we have no trouble whatever with quick starting of the drum or other problems relating to velocity or amplitude modulation. The flutter in this machine, by the as yet nonaccepted standard, measures somewhat less than $1/10$ of 1 per cent and the flutter rates are practically all above 100 cycles, as is customarily found in most magnetic recorders. With regard to the Davis Drive, we are quite cognizant of the contributions of Dr. Kellogg and others. It is to be regretted, however, that they never saw fit to introduce it to the industry. The Western Electric Company, as far as I know, was the first to introduce the tight-loop type of drive and the Davis Drive is so called for the reason that it was recognized by the Academy and given an award; and in that award, the name "Davis Drive" was created. The name "Davis" was not given to the drive by the Western Electric Company. The Davis Drive itself is covered by a U.S. patent, the principal patentable feature being the common spring connecting the two compliant rollers. The tight loop thus created eliminates the necessity of the customary pressure-pad roller. Shortly after we introduced this tight-loop drive, our competitors brought out a similar one. Perhaps Dr. Kellogg could enlighten us on why that happened.

Dr. Kellogg: Dr. Frayne has brought up the matter of the introduction to the industry of the filtering system which depends on damped movable idler-rollers. Certain obstacles to the use of this system were cleared away in the early 1940's, but the war years were not the time to jump to new models, particularly when the older ones were doing well, which was certainly true of the RCA rotary stabilizer soundheads. But our first postwar recorders, and 16-mm projectors, utilized filters of the damped, movable-idler type.

Carbon Arc Characteristics That Determine Motion Picture Screen Light

By M. T. Jones and F. T. Bowditch

In a carbon arc motion picture projector, definite relations exist between screen light on the one hand, and the arc current, current density, carbon size and the speed and collection angle of the projector optical system on the other. Measurements on more than 100 standard and experimental carbon arcs, with carbons ranging in size from 9 mm to 16 mm, have provided data to establish these relationships. Conditions are defined which are of importance in the matching of an optical system to a given arc, or vice versa, and for obtaining optimum performance in any situation involving screen distribution, amount of light and preferred current.

In an earlier paper[1] a method is described for calculating motion picture screen light from measurements of brightness over the carbon arc crater as viewed from selected angles, and from a consideration of the characteristics of the particular optical system involved. This method has now been applied to a variety of standard and experimental carbons, and the resulting data analyzed to establish certain significant relationships which form the subject of this paper. These relationships are concerned with the distribution and the amount of light delivered to the motion picture screen, as these are determined by the arc current, the current density, the size of carbon and the collection angle and speed of the optical system.

As an illustration of the basic data from which these trends are established, calculations made from measurements on three experimental trims, each at its maximum operating current, are shown in Figs. 1, 2 and 3. In this, and in all subsequent cases throughout this paper, these calculations are made according to the method previously described,[1] for the one best-focus condition giving maximum screen light. Each of these curves shows, on the left, the lumens through the motion picture aperture and, on the right, the light distribution across the aperture, each over a range of light-collecting angles from the source, and for a series of optical speeds into the aperture. Light losses due to absorption, shadowing and vignetting, which always occur in varying degree in any specific optical system, have not been included in these present calculations, a permissible simplification since only relative values are considered in the conclusions drawn here. A suitable loss correction of approximately 50% would

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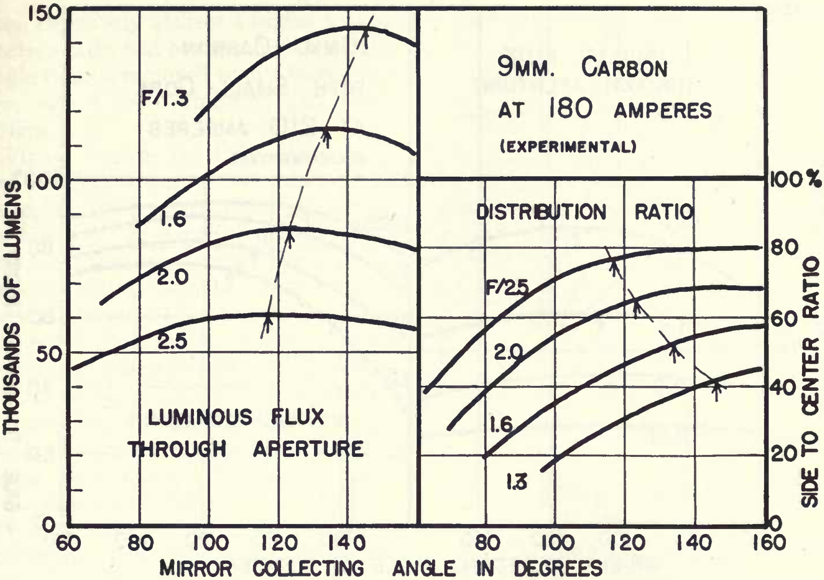

Fig. 1. Screen-light characteristics of an experimental 9-mm high-intensity positive carbon at its maximum operating current in water-cooled jaws.

NOTE: *All light and distribution values throughout this paper are based upon the best-focus condition giving maximum screen light.*

have to be applied to the lumen values given in this paper in order to determine the actual screen-light level in any particular instance. As an example, crater light measurements on an 8-mm to 7-mm "Suprex" trim at 70 amp, calculated for an $f/2.0$ mirror, predict a flux of 27,600 lm on the aperture, compared with 14,000 lm motion picture screen light realized in practice. This is because mirror absorption and reflectance losses, plus shadowing due to the positive head, etc., amount to about 20%; while of the total lumens passing the film aperture, no more than about 65% reaches the screen due to a combination of spill-over, vignetting and glass transmittance losses at the projection lens.

With respect to the aperture-lumen variations shown by Figs. 1, 2 and 3, these confirm the earlier conclusion[1] that maximum luminous flux is not necessarily obtained at the maximum collection angle; the simple concept that a bigger collection angle picks up more light from the source and hence delivers more light to the motion picture screen fails to work out. With a fixed speed into the aperture, the optical geometry is such that the magnification of the crater image on the aperture increases as the pickup angle increases, thus introducing a loss factor, working against the greater light collection. The light distribution characteristics of high-intensity carbon arcs are such that a collection angle is reached at each speed beyond which more light is thrown outside the aperture by the enlarged image than can be collected by the higher pickup angle. The exact pickup angle at which this maximum light value occurs will depend in each instance on the particular light distribution characteristics of the carbon in question. A small carbon, for instance, with a peaked light distribu-

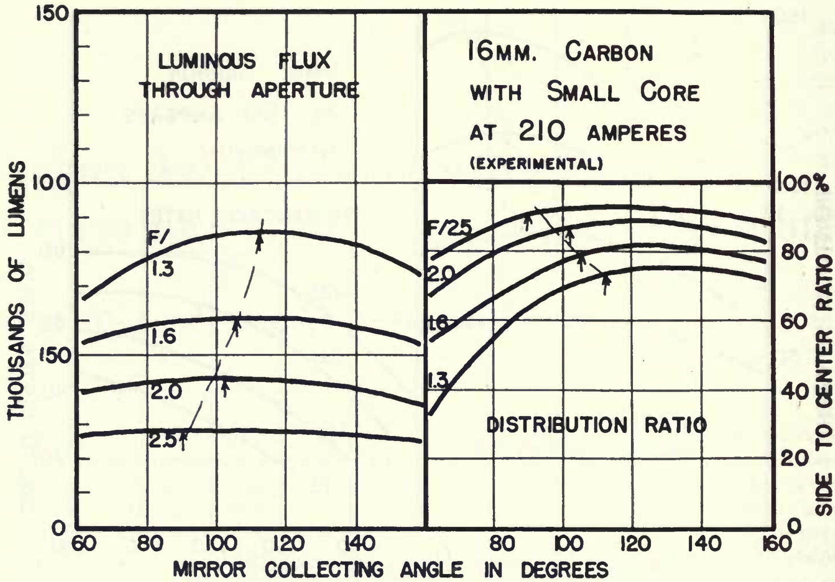

Fig. 2. Screen-light characteristics of an experimental 16-mm high-intensity positive carbon, with small core, at its maximum operating current in water-cooled jaws.

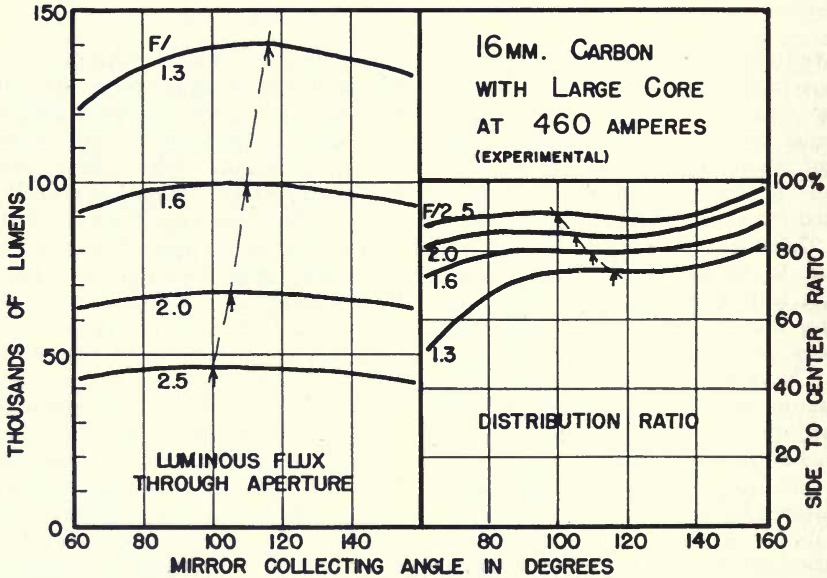

Fig. 3. Screen-light characteristics of an experimental 16-mm high-intensity positive carbon, with large core, at its maximum operating current in water-cooled jaws.

tion, effectively utilizes a higher magnification ratio and hence a higher pickup angle than is required with a larger carbon with a more uniform light distribution.

Figure 1 gives the light characteristics of an experimental 9-mm carbon operated at 180 amp, a very high current for this size. It is seen that high collection angles are effectively utilized at the various optical speeds to give good screen light values, but at comparatively low distribution ratios. Figure 2 shows the similar characteristics for an experimental 16-mm carbon with a small core, operated at 210 amp. Here a much smaller collection angle gives maximum screen light, and the distribution ratios are considerably higher.

Figure 3 shows the light-output characteristics of another experimental 16-mm carbon with a large core, operated at 460 amp, the maximum current used with any of the approximately 100 positive carbons upon which the conclusions of this paper are based. Particularly with this carbon, the light output and distribution ratio are comparatively insensitive to the choice of collecting angle, since, with the large core and high current, the effective source is quite large and of more uniform brightness.

It might be noted that in no case is a 100% distribution ratio reached. Particularly with the large-cored 16-mm carbon at $f/2.0$, the effective source size is quite sufficient to fill the aperture completely from all angles of view. However, the crater of any high-intensity carbon is always brightest near the center, and this peak is carried through as higher illumination in the center of the screen.

Data such as those shown in the preceding figures have been correlated for approximately 100 different positive carbons, both production and experimental types, of 9-, 11-, 13.6- and 16-mm diameter. It is, of course, recognized that the smaller 7- and 8-mm

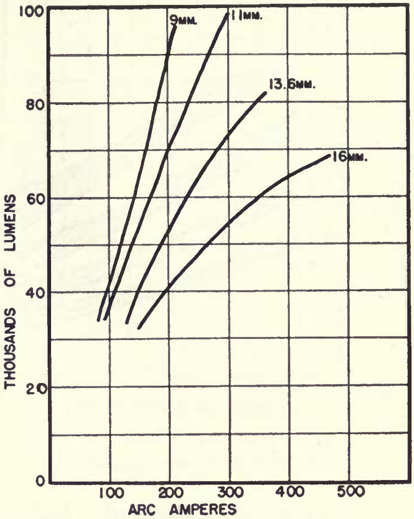

Fig. 4. Relation between screen light and arc current at an optical speed of $f/2.0$.

"Suprex" carbons are very important items, commercially, although they were not within the scope of the investigation reported here. Certain basic behaviors have been disclosed by these correlations. The first such relationship is that between screen lumens and arc current for various carbon sizes and optical speeds. Figure 4 shows this relationship at a speed of $f/2.0$ and for carbons of 9-, 11-, 13.6- and 16-mm diameter. Each curve results from measurements on a number of different-type carbons of a given size, each carbon represented by a single value determined at the maximum stable current for that carbon. For example, referring to the extreme points on the curve for the 16-mm size, one type of 16-mm positive carbon was found to give 32,000 lm at its maximum current of 150 amp; while another 16-mm positive carbon of very different construction gives 68,000 lm at its maximum current of 460 amp. The curves of Fig. 4 show the smallest carbon most efficient in current utilization, although, as will be indicated later,

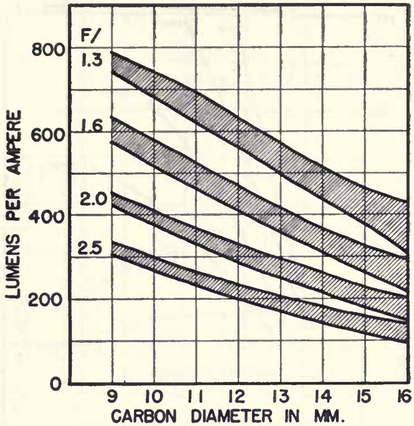

Fig. 5. Current efficiency in screen-light production.

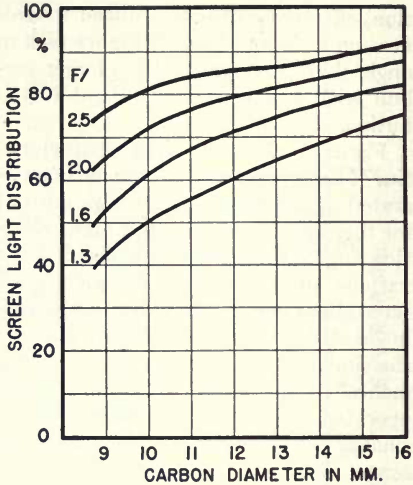

Fig. 6. Screen-light uniformity; side-to-center brightness ratio.

factors other than maximum current efficiency are involved in the choice of a preferred trim for a particular situation. It will be noted that the curves for the 13.6- and 16-mm carbon sizes are concave downward, indicating a falling-off in current efficiency with increasing amperage on a given size, which is probably the result of the inability to cool the larger diameters as effectively as the smaller. For instance, the 16-mm carbon at 150 amp gives more than 200 lm/amp; while the larger-cored 16-mm carbon at 460 amp gives only 150 lm/amp. This relationship is shown more directly by Fig. 5 which utilizes the data shown on Fig. 4, together with similar data calculated for the other optical speeds indicated. Here lumens-per-ampere are plotted against carbon diameter for each of four different optical speeds. Each curve is represented as a band, including the extremes in current efficiency encountered with each carbon size. Here again, the higher current efficiency of the small-diameter carbon is confirmed for each of the optical speeds investigated.

The data so far have been concerned only with current efficiency, and if this were the only criterion, the smallest possible carbon would always be chosen for a given job. However, no consideration has yet been given to the screen-light distribution ratio, the burning rate of the carbon or the color uniformity of the screen, all important factors in making a choice in any particular situation.

Figure 6 shows the variation in screen-light distribution ratio with carbon size, at the same optical speeds previously considered. Here the decided improvement in screen-light uniformity with increasing size is effectively demonstrated, particularly as the optical speed increases to give a steeper slope to the curve. The data shown in Fig. 6 represent the average for all the carbons tested, individual values showing some scattering around these curves, but not sufficient to invalidate the general trend. It should be pointed out, however, that, contrary to the general indication of Fig. 6. all 9-mm carbons, for instance, do not yield a lower screen-light distribution than all of 10-mm size. In fact, the reverse is sometimes the case in practical service comparisons. Different ratios of core to shell diameter, different methods of construction and burning, all contribute to the scattering previously described.

Two additional factors contribute to the screen distribution value actually achieved in a given commercial situation. The first is due to the slight departure in shape of all commercial lamp mirrors from the perfect ellipse assumed in the present calculations. Instead of all the crater images from all angles of view being precisely centered in the aperture, they are displaced in practice, by normal errors in mirror shape, to spread the light in less peaked fashion, but with negligible loss in total lumens on account of this spreading. In the second place, the projectionist, in adjusting his optics to give the best-looking screen, may decide upon a slightly out-of-focus setting, and sacrifice somewhat on screen light in favor of a flatter screen. The distribution values of Fig. 6, therefore, are not necessarily the same as those which would be obtained in a practical projector assembly, although the basic trends between sizes and optical speeds are as indicated.

Let us consider next the consumption rate of the carbon. This depends so much on carbon design, on the method of burning, whether the carbon is plated or unplated, whether it is burned with or without current jaws, and with or without water-cooling, that no simple relationship exists. However, in situations where equivalent screen light is given by carbons of different sizes the smaller carbon will always burn the faster. The exact magnitude and economic significance of this difference requires determination in each specific case, and is always an important factor to be considered. Blowing of the arc according to principles recently defined by Dr. Edgar Gretener,[2] is also a major factor in the determination of current and carbon efficiency. Apparently the light secured at a given current is very substantially increased by this blowing, while the carbon consumption per unit of light output is less markedly affected.

With respect to screen color, it is most difficult to express color differences

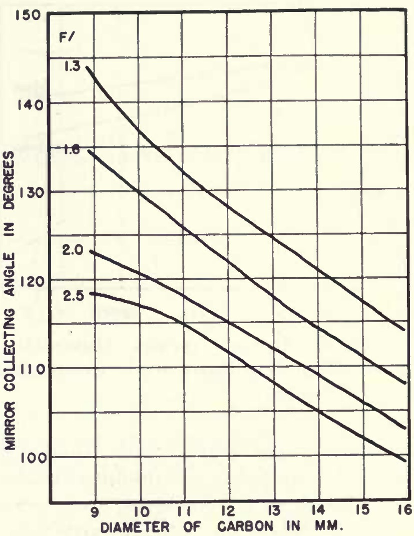

Fig. 7. Collecting angle giving maximum screen light.

in terms of numbers of true comparative significance, and no attempt has been made to do this with the various trends reported here. However, the larger carbon gives a more complete filling of the aperture from all angles of view, and also tends to give a more uniform screen color in any comparison of different sizes at equivalent light levels. Further, with the larger-sized carbon, screen light and color uniformity is better maintained over a wider range of maladjustment of the positive-carbon position.

It was previously indicated that the smaller carbon requires a higher collection angle for maximum screen light than does the larger carbon. This general relationship is indicated for four different optical speeds by the curves of Fig. 7. The increasing slope at the higher speed shows that this effect of carbon size becomes more pronounced as the speed increases.

Finally, the relationships plotted in Fig. 8 show that increases in optical speed into the aperture do not result in as great increases in illumination as the

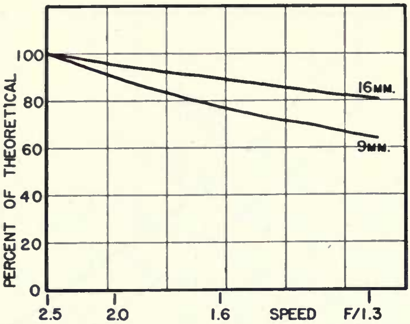

Fig. 8. Actual versus theoretical gain in screen light with increasing optical speed.

relative optical speeds alone would predict. Compared to the illumination obtained with an $f/2.5$ system, an increase to $f/2.0$ should theoretically give 6.25/4.00 or 1.56 times as much illumination. The ratio calculated with 16-mm carbons is 1.48, and for 9-mm carbons, 1.40—95% and 90%, respectively, of the theoretical amount. As might be expected, this departure from the theoretical is greatest for the smallest carbon, the reason being that the crater images on the aperture are not sufficiently large to fill the aperture completely at all angles of view, and that the brightness distribution across the crater is most peaked for the smaller carbons.

This paper thus defines certain basic relationships which should be recognized in the most effective development of the combined arc carbon and optical system to do a given job. Broadly speaking, a small carbon can be utilized to give highest current efficiency; this requires the use of a high collection angle, gives a less uniform screen-light distribution and screen color, and is more sensitive to light and color variations as the carbon is moved from the exact focal position. The larger carbons operate with lower current efficiency but give a higher quality performance in all other respects, at a higher cost. The choice in a particular situation should be based upon a balance of these various factors as applied to the specific economic considerations involved. As in other fields, there are proper applications for many possible combinations of cost and quality.

References

1. M. T. Jones, "Motion picture screen light as a function of carbon arc crater brightness distribution," *Jour. SMPE*, vol. 49, pp. 218–240, Sept. 1947.
2. E. Gretener, "Physical principles, design and performance of the ventarc high-intensity projection lamps," *Jour. SMPTE*, vol. 55, pp. 391–413, Oct. 1950.

The RCA PT-100 Theater Television Equipment

By Ralph V. Little, Jr.

The design of the first commercial theater television equipment is based on the experience gained from installing and operating earlier developmental equipments in theaters. Designed to augment the standard theater sound equipment, the PT-100 Television Equipment is intended to combine maximum reliability with performance limited only by the quality of the incoming signal.

Since the early stages of its development, engineers have visualized television as a natural entertainment medium for the theater, comparable to that of motion pictures. Years of engineering research and development, with special attention directed to the production of theater-size pictures have been rewarded. Theater projection television is no longer an engineer's dream but a current reality.

The first theater television equipment was demonstrated in 1929 at the RKO Proctor Theater in New York; the equipment used a mechanical scanning disc to produce a 48-line picture which was formed by video modulation of the light beam from an arc lamp source. During the interval of 20 years the all-electronic television system was devised with the substitution of the kinescope for the scanning disc followed by the addition of the iconoscope for use in the camera.

Paralleling the development of the basic technology of electronics, Dr. Epstein and Mr. Maloff were concentrating their efforts on the design of high-intensity kinescopes and of more effective optical systems which led to rapid advances in projection television during the years 1937–1940. By 1940, a modern prototype projection unit emerged from the laboratories to be demonstrated at the New Yorker Theater in 1941. The goal was now in view, but World War II delayed further development.

The interest of the film industry was enlisted in 1945 and 20th Century-Fox and Warner Bros. cooperated to have two of the 42-in. optical giants built by RCA. These equipments have been described and were demonstrated on several occasions during 1947 and one is still in use as a standard of excellence at the 20th Century-Fox Television Laboratory.

With this background of accumulated experience in the fields of television and

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tube techniques, we were ready to establish a product design of a theater television system.

Surveys were made of a number of representative theaters to determine the physical parameters into which a projection system might be integrated. There were many factors to be considered such as the requirements of performance, the limitation of present theater structures and the economics of the purchase and use.

Using initial prototype designs as a basis, a specification was submitted by 20th Century-Fox as a suggestion of the type of equipment which might be suited to the ultimate commercial use in the theater. Earl Sponable and H. J. Schlafly have been actively cooperating for four years in the development phases of the project and their efforts have served in a large measure to bring our new design to the industry. Warner Bros., through Col. Levenson, contributed their suggestions.

The goal of both the engineer and the theater industry is to develop theater television projection to equal or excel the industry standards for 35-mm motion picture film projection; under controlled conditions of pickup and transmission, the goal appears as a possibility. Evolution of an 8-mc video channel, used under ideal conditions of equipment adjustment, including correction for proper tone scale rendition, and having a high signal-to-noise ratio, should reproduce all the information in a frame of 35-mm motion picture film. The factors which require attention to produce the ultimate in picture acceptability are: (1) picture detail; (2) freedom from granular or other structure; (3) signal-to-noise ratio; and (4) tone-scale rendition.

Picture detail and structure must be discussed together as they have to do with the transmission bandwidth available. The present television broadcast channels limit the practical bandwith, via air transmission, to approximately 4.25 mc. The number of scanning lines is now 525, permitting a resolution of 340 lines horizontally and 400 lines vertically as seen by use of the Monoscope test pattern. At a 4:1 viewing distance, which is the minimum for home viewing, the scanning lines cannot be resolved by the eye so that the standards are considered adequate.

In order to accommodate the theater patrons, who will be closer to the screen than the minimum 4:1 distance, more picture detail and a greater number of scanning lines will be desirable. The selection of the number of scanning lines is a function of the economical bandwidth and a compromise on the balance between the resolution of the picture elements in the horizontal and vertical dimensions. With the 8-mc video band, selected for an example, we can determine the resolution capabilities of such a system.

It is to be noted that the present 4.25-mc broadcast standard permits a balanced horizontal and vertical resolution of approximately 400 television lines. An increase in the number of scanning lines, while retaining the bandwidth, reduces the horizontal detail as shown in Table I. The data indicate that an 8-mc system will give a balanced resolution when using 625

Table I. Television Resolution.*

		525	625	735	819
Vertical		488	582	683	762
Horizontal, Bandwidth	4.25 mc	340	283	240	216
	8 mc	640	533	453	407

*Scanning lines/60 fields, interlaced.

lines. The RCA PT–100 equipment has been designed to utilize the capabilities of a full 8-mc video channel.

The signal-to-noise ratio is an extremely important factor, probably the most important, if emphasis is to be placed on any one item. Motion picture film noise level, which until recently has not been quantitatively measured, should be the basis for an acceptable noise figure; the value of 42 db for the electrical maximum signal-to-noise has been suggested. The type of noise is important, as impulse type can be extremely troublesome because of its effect on the keyed d-c setting circuits. Also single-frequency noise will beat with the scanning frequency to form interference patterns which can be noticeable even though low in level

The fourth factor, tonal rendition, is also important and is dependent on the operating conditions of the camera in particular, and on the operation of the projector as a secondary effect.

When the camera characteristics can be well enough standardized, correction circuits can be introduced to enable the projector to produce pictures of photographic reproduction qualities. The SMPTE Committees on theater television are studying these problems and will be able to make recommendations to the industry for the necessary standards.

Details of the PT–100 Equipments

The design of the PT–100 projector is predicated on the choice of two elements of the projector: the kinescope and the optical system. The projection kinescope chosen for the design was a 7-in. tube to be operated at 80,000 v; it was desirable to choose the smallest tube consistent with high performance in light output, in resolution, and in detail contrast.

With the kinescope size chosen, the RCA Tube Division undertook the task of developing the 7NP4 to fill the needs of this design, which is described in detail in an accompanying paper in this issue of the Journal.

Considerations of optical design require a careful analysis because they are the most costly elements of the equipment. Their selection had to be predicted on available manufacturing techniques for volume production of the glass blanks, the final grinding and the aluminizing. The cost of the optics and their mounting increases approximately as the square of the diameter. The production of the 42 in. mirror by laboratory methods was one thing on which cost was secondary, but the practical considerations indicated that a 26-in. mirror would present a good compromise.

With the kinescope size chosen and the mirror size roughly determined, it was a problem of optics to arrive at the proper design center which includes the faceplate of the kinescope as an element of the optical system.

The effective focal length finally chosen was 15.515 in., and Fig. 1 shows a chart of the operating conditions; the nominal projection throw is 62 ft from the face of the kinescope to the screen for a 20-ft wide picture. Since the "Schmidt" type system, as in the case of most other optics, is a fixed magnification device, the only variable is the picture size on the faceplate. Arbitrary limits are shown in the figure to indicate a degree of flexibility. The diagonals represent the diagonal raster sizes on the kinescope, the nominal size being 6¼ in. and shown as the center line.

The percentage figures show the relative screen brightness for various conditions of operation with 100% for the nominal light output at the design center.

With the limitation of the optics determined and the balcony location of the projector established, it was decided that a very minimum of equipment should be located in the theater auditorium.

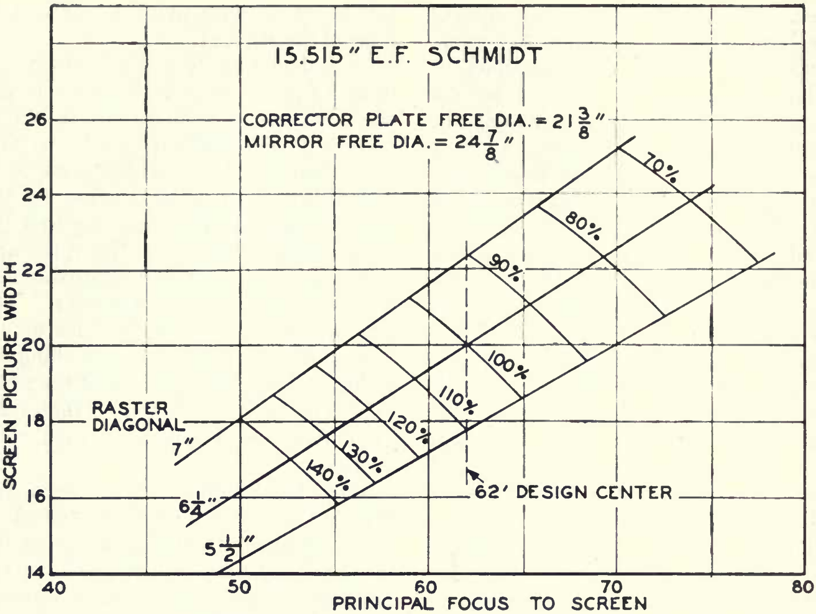

Fig. 1. Chart of 15.515-in. effective focal length lens operation.

Figure 2 gives a typical theater cross section showing how the projector would fit into a balcony-type house. The screen, due to the shallow depth of focus of the projector, is mounted normal to the projection axis. The arrangement in a non-balcony or stadium house would require that the nominal throw be kept and that the projector be mounted on a retractable boom from the ceiling.

The characteristics of the modulation, or video amplifier, made it necessary to place this element adjacent to the kinescope. In past designs it had also been necessary to include the horizontal scanning wave amplifier near the kinescope deflection yoke, but this required more cabling to the projector and a great deal of physical space; therefore, a premise of the present design was to place all of the deflection equipment in the booth racks. The only electronic element of the equipment now remaining in the projector housing is the video power amplifier. The projector consists then of the projection kinescope (the 7NP4) the optical elements, a 26-in. mirror with a 22-in. correction lens together with the mounting or support of these elements. The electrical equipment is kept to a minimum with the required video amplifier, a blower for cooling the kinescope faceplate, and the necessary terminal boards to facilitate interconnecting wiring.

The equipment location can be seen in Fig. 3 which is a photograph of the projector with one-half the outer housing removed. The wiring is accessible by lifting the top protective cover which reveals the terminal board wiring side of the video amplifier. The amplifier is hinged to be tilted up and to the side, making the tube side of the chassis accessible and permitting adjustment or replacement of the kinescope. The projector is interlocked through the control panel to remove the high voltage if the cover is raised; the interlock also actuates a shorting arm which contacts the

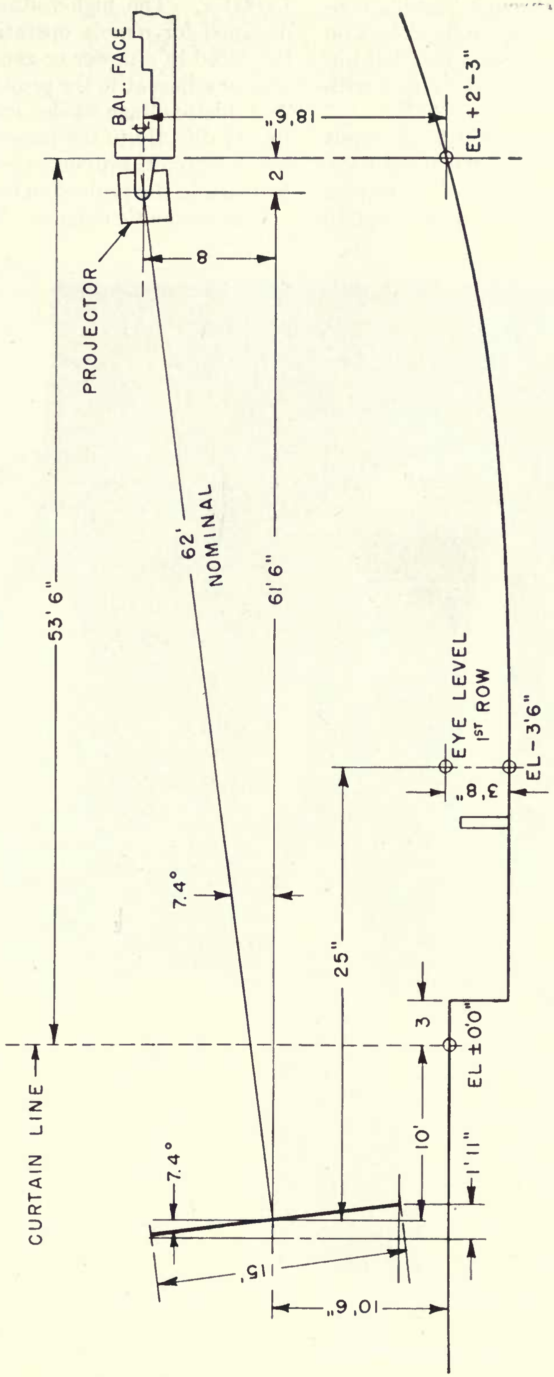

Fig. 2. Typical theater, cross section.

high-voltage feed through bushing connecting the circuit to ground. A lock on the cover gives added safety so that unauthorized persons cannot tamper with the equipment.

High voltage is supplied from a unit designed to furnish the 80,000 v for the accelerating anode and also to furnish the focusing voltage of approximately 18,000 v. The high-voltage supply is designed for remote operation and can be placed in a power or generator room near or adjacent to the projection booth. Two high-voltage cables lead from the supply directly to the projector and the control circuits are connected to the control rack in the projection booth.

The schematic diagram, Fig. 4, shows

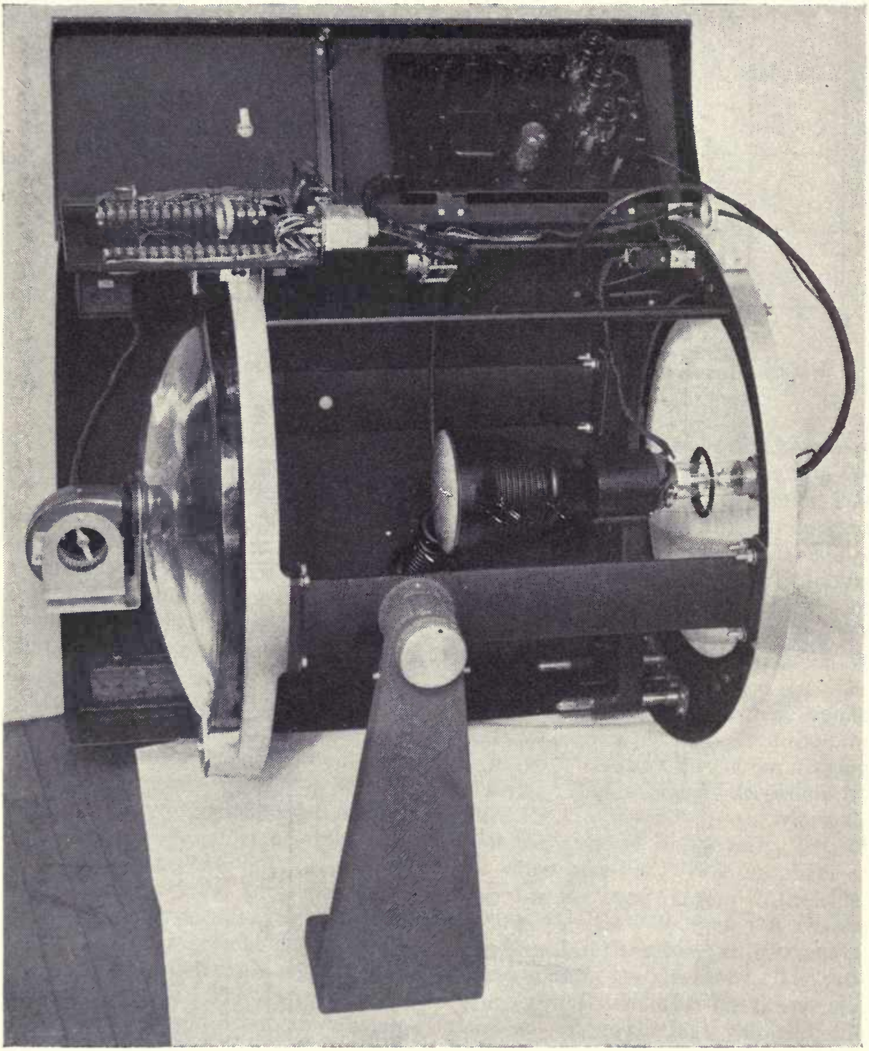

Fig. 3. PT-100 Projector, cover removed.

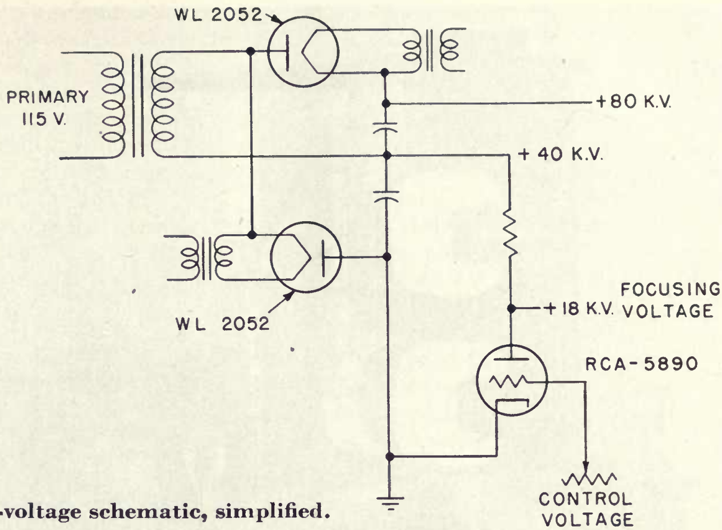

Fig. 4. High-voltage schematic, simplified.

the elements of the supply consisting of a 40,000-v transformer in a voltage-doubling rectifier circuit; the rectifier tubes are type WL2520 tubes. A special feature of this supply is the shunt regulator tube developed for remote adjustment of the focus voltage about its mean value of 18,000 v.

The tube for focusing is the RCA 5890; its use eliminates variable resistors with their attendant difficulty of insulation and stability at these high voltages. In addition to the basic elements, the high-voltage supply contains protective circuits to short the output voltages when power is removed. Metering circuits are also provided with remote indication on the control panel to show the proper functioning of the equipment; the metering shows the voltage and current being developed by the supply. In operation the meter gives knowledge of the proper functioning of the power supply; the current reading indicates that the kinescope is active and drawing power from the supply. The voltage indication shows the operation of the step-starting timer and shows when full voltage has been applied to the projector.

Figure 5, a photograph of the high-voltage supply, shows the unit with the rectifier tubes exposed for servicing. By loosening four nuts this panel may be raised to the position shown. Through very conservative design it is expected that the rectifier tubes will last from three to five years; in fact, the entire unit will give years of uninterrupted service with a minimum of servicing. The only service function consists of rotating the rectifier tubes at stated intervals to keep the spare tube properly activated.

Mechanical and Electrical Considerations

The block diagram, Fig. 6, shows the location of the various parts of the system. There are the three logical divisions of the equipment with their respective locations: the projector located in the theater, the projector control in the projection booth, and the high-voltage supply in the power or generator room.

The location of the operating equipment in the projection booth gives precedence for equipment design to conform to time-tested procedure of front

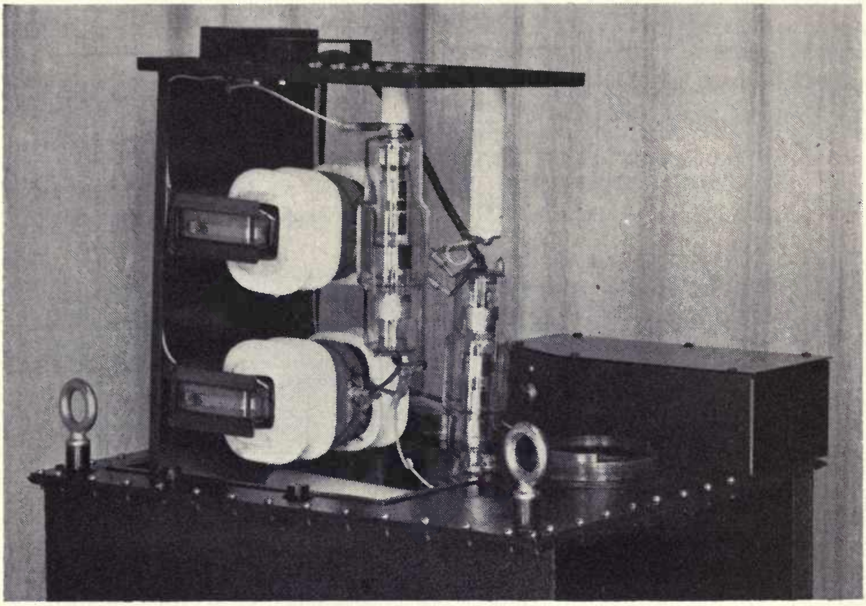

Fig. 5. High-voltage supply, tube-shelf open.

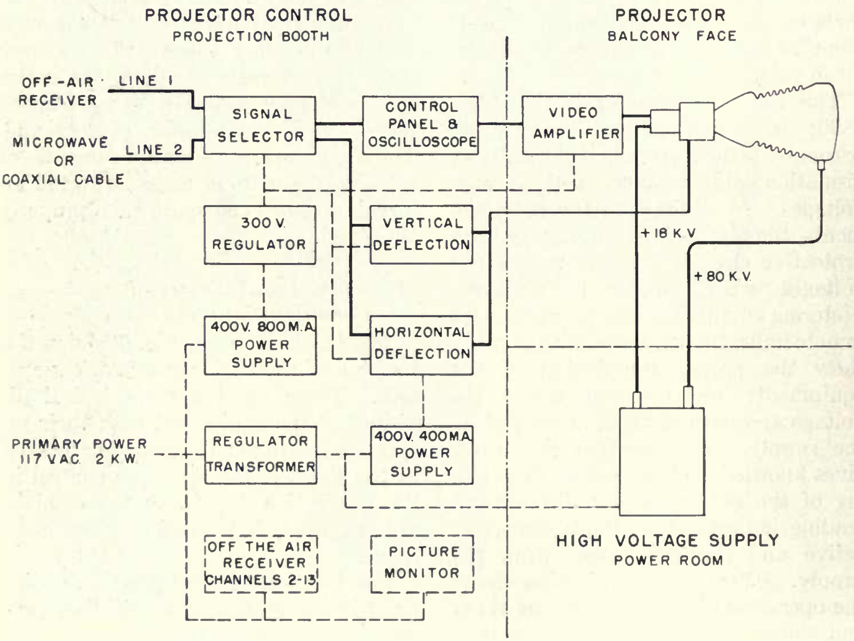

Fig. 6. PT-100; block diagram.

servicing of the equipment for theater work. The major electrical considerations, of course, are the Underwriter's requirements, and in addition, the utmost in component reliability due to the economic necessity of installing single-channel equipment with no stand-by or emergency service available.

The booth equipment consists of two short racks, one the projector control, the other the monitor rack. There are ten major units of equipment as shown by their respective blocks, and in addition, the necessary terminal boards and a high-voltage control panel.

The signal would enter the signal selector, which contains the video amplifier and synchronizing circuits, to be distributed to the control panel, the vertical deflection, and horizontal deflection units. An 800-ma, 400-v power supply makes regulated 300 v available through the regulator unit. The 400-ma, 400-v power supply furnishes power for the horizontal deflection and is fed from a 1-kw, regulating-type transformer which also provides a standard of reference for the high voltage. An off-the-air receiver and picture monitor complete the complement of the racks.

A typical chassis unit is shown in Fig. 7, as it is mounted in the rack and ready for operation. A removable cover can be taken off to check the tubes or the fuses. All individual chassis have the primary power fused, as are the plate voltages which have neon indicators on their circuits. The unit shown is the vertical deflection amplifier; Fig. 8 shows the interior exposed for servicing or adjustment of the infrequently used internal controls: the vertical hold, vertical size, vertical linearity and, on the rear panel, the vertical centering.

Miniature tubes are used whenever possible and, in order to avoid mounting of parts on those small tube sockets and to make the unit more accessible for manufacture and servicing, resistor boards are used to produce this trim design. The mechanical design was so proportioned to permit standardization of the chassis blanks and the covers; in addition, it presents a uniform overall appearance.

Circuit Operation

Electrically, the protection of the 7NP4 kinescope required a major part of the design effort. The expense of the

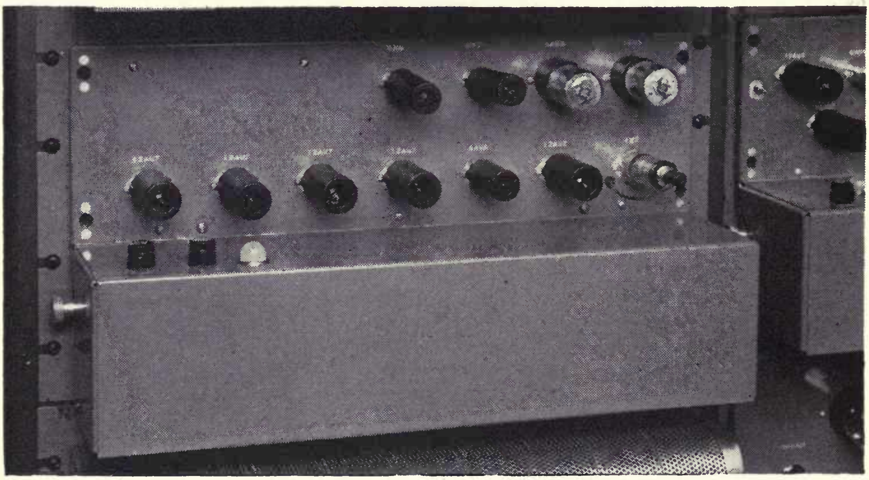

Fig. 7. Vertical deflection chassis, without cover.

kinescope and the necessity of ensuring that the tube fulfill its life expectancy made electronic protection a must item. Scanning failure could cause the faceplate of the tube to be burned so as to make it unusable and in the extreme case, with high-voltage beam concentrated on a single spot, that is without either vertical or horizontal scanning, it could melt a hole in the faceplate of the tube.

Protection to the kinescope has been provided for the following contingencies:

1. Open or shorted deflecting yoke,
2. Lack of drive due to tubes,
3. Loss of supply voltages,
4. Overdrive of kinescope (positive grid).

In operation, primary power is first applied for all electron-tube heaters and to the bias supply. A relay on the bias supply then closes, connecting primary power to the plate power supplies. Scanning will now be generated, but a series of interlocks must now be closed before the high voltage can be applied.

The following protection circuits must be functioned properly: the horizontal scanning; the vertical scanning; the electromechanical interlock on the projector cover must be closed; the vault high-voltage access door must be closed; then the high-voltage control circuit may be actuated. During operation excess video drive could damage the kinescope if it were not protected by an instantaneous bias control.

The most important consideration in the design of the protection system is the speed with which failure can be detected and corrective measures taken and, in addition, the circuits must fail safely. The circuits operate in such a manner as to drive the kinescope to beam cut-off (and this must be accomplished in a matter of less than 50 μ sec) and then the relays operate to remove the high-voltage power.

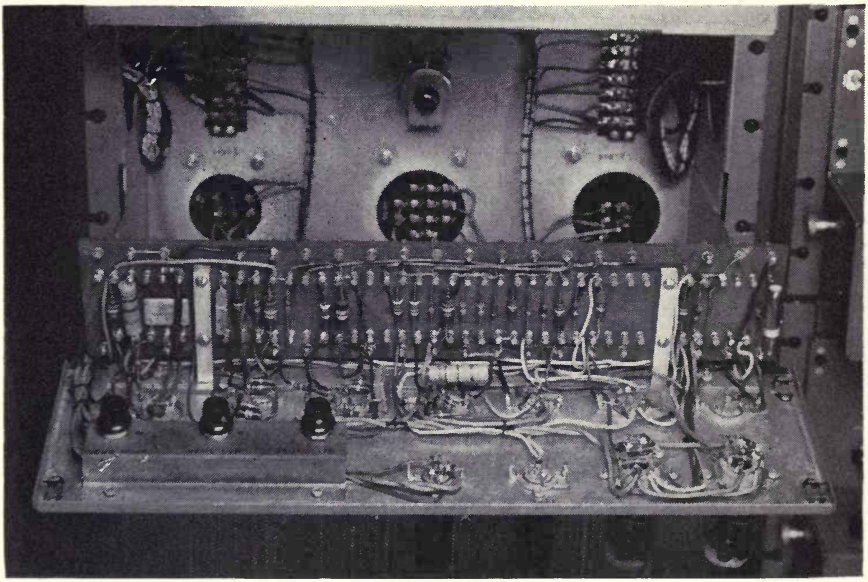

Fig. 8. Vertical deflection chassis, inside.

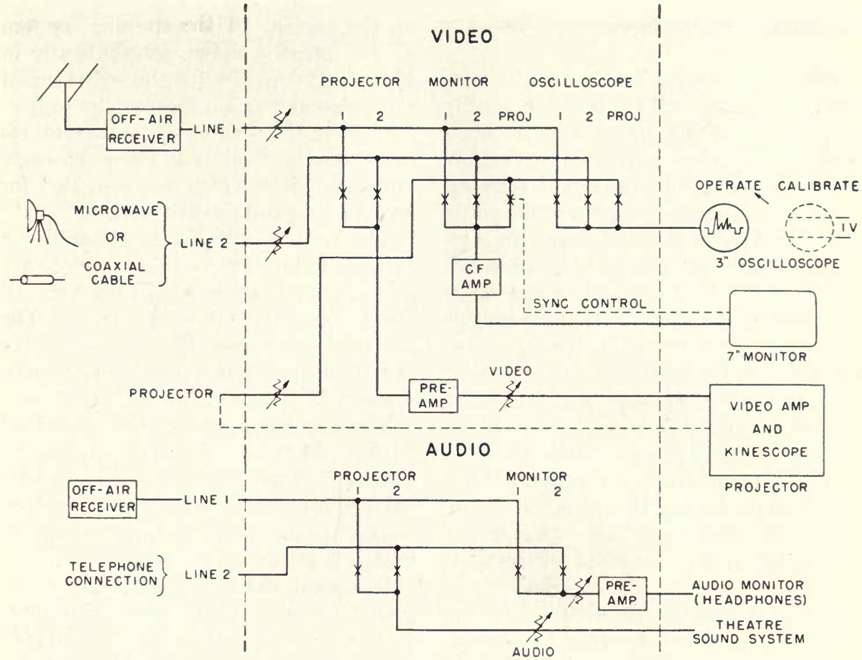

Fig. 9. Signal selector; simplified switching schematic.

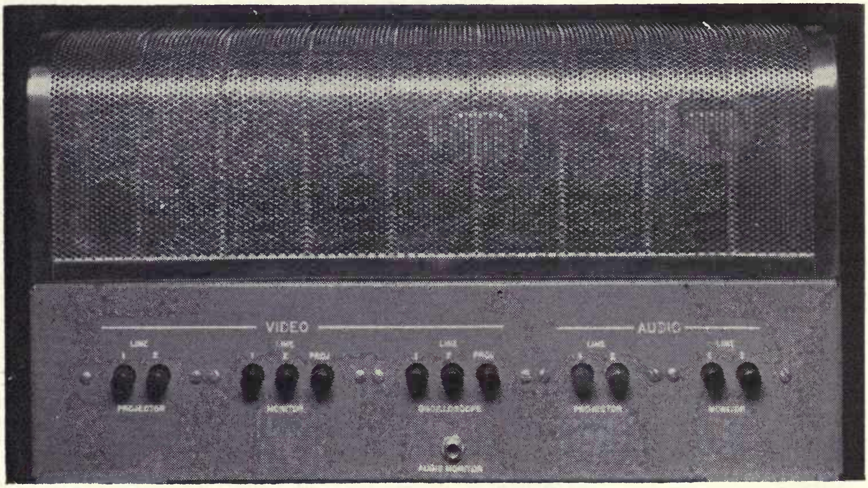

Fig. 10. Signal selector unit.

Equipment Operation

We must consider how the equipment will be operated in the projection booth, how the incoming signal will be controlled, and what points of operation should be checked. A signal selector panel was designed to facilitate the complete checking of the equipment prior to projection of the picture to the screen. Experience gained had shown the value of a system of checks to be made by the operator prior to show time. The switching will take care of two incoming lines each of video and audio signals, and also monitor the projector before the high-voltage power is applied.

An off-the-air receiver is provided as a signal source during the initial period of use, or as a source of test signal if the normal signal is to come via microwaves or coaxial cable. The receiver is normally connected to Line 1 and an alternate signal is connected to Line 2. As auxiliaries to the signal selector a 7-in. picture monitor and a 3-in. oscilloscope are used to check the projector functions without projecting a picture on the screen. The switching system of the signal is shown schematically in Fig. 9. It provides for the switching of the video and audio lines to the projector and to the theater sound system, respectively, as well as to an oscilloscope and a monitor which are provided for level setting and quality control.

The projector video amplifier has a cathode-follower video return which supplies a signal, attenuated by a ratio of 100:1 from the kinescope drive. The return signal is marked *Projector* on the signal selector, and the incoming signals marked *Line 1* and *Line 2.*

The oscilloscope is a 3RP1 provided with a 60-cycle sine-wave sweep, d-c setting for the vertical deflection, and a calibration circuit set to provide 1 v, peak-to-peak, marker lines when its switch is set on calibrate position.

In operation, Lines 1 and 2 are adjusted for level using the oscilloscope, and then, when normal level is provided to the kinescope, by operation of the video attenuator the level for the projector can be set by adjustment of the return line from the projector.

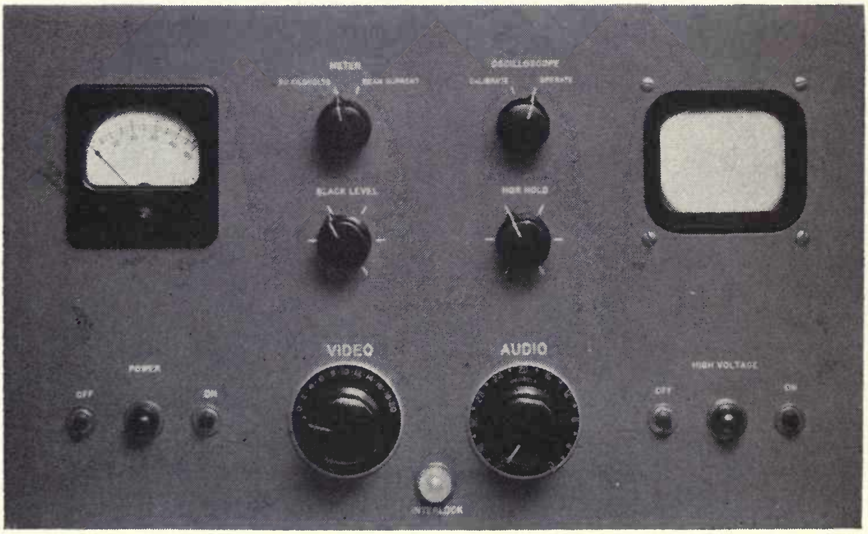

Fig. 11. Control panel.

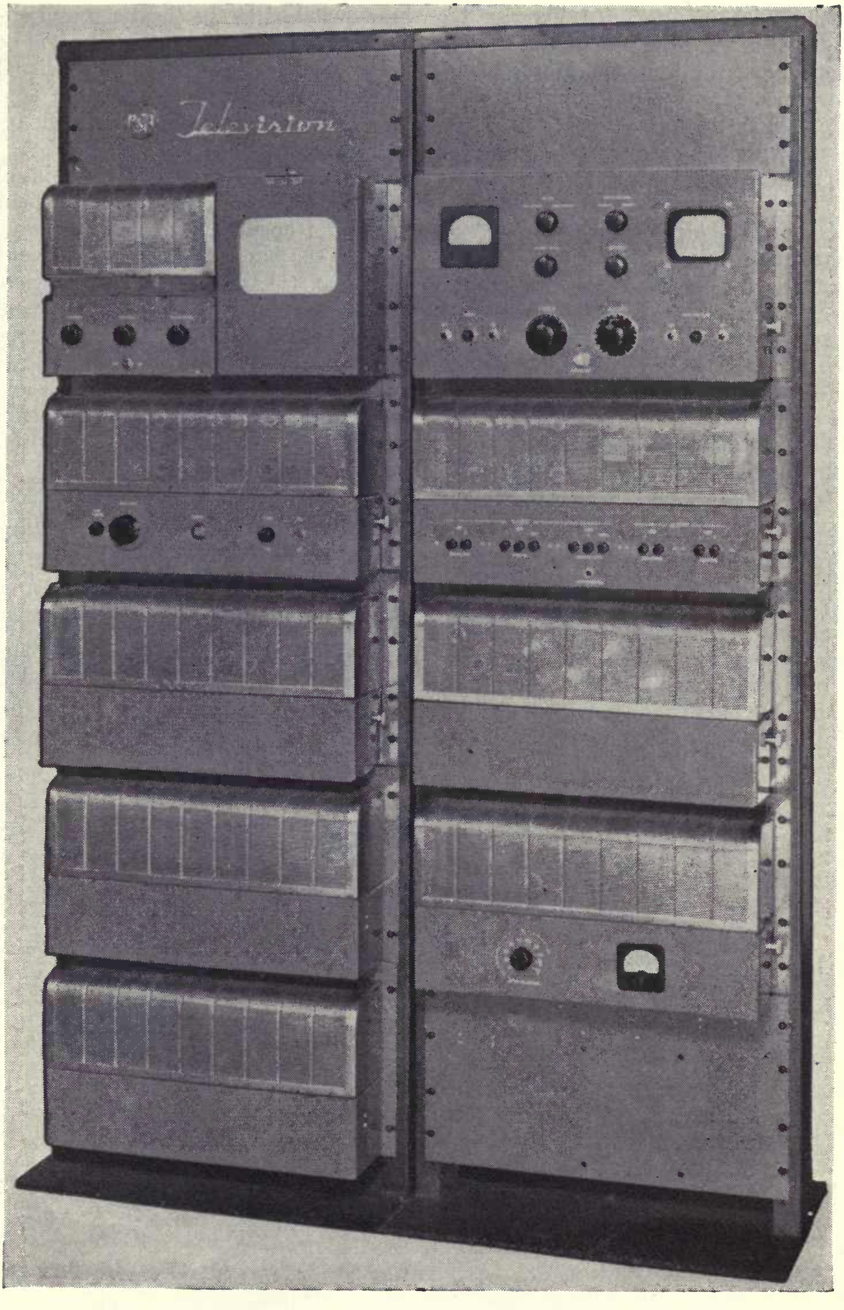

Fig. 12. PT-100 control and monitor racks.

The 7-in. monitor can likewise be switched to view the pictures on the incoming lines or from the kinescope in the projector; when on the projector, a complete system-operation check is obtained without requiring the picture on the theater screen.

The monitor is provided with driving pulses from the projector scanning circuits; it then shows the operation of the scanning lock-in as well as the picture quality; otherwise the monitor is synchronized from the incoming signal. The power supply for the monitor is self-contained making it independent of the operation of the projector.

The audio signal can be obtained from either Line 1, which is the off-the-air receiver, or Line 2 which may be a telephone line connection. Projector audio would normally be connected to the theater motion picture sound system and is provided with an attenuator for level setting. In order to be able to check the presence of incoming signal before operations, a preamplifier and headphone circuit are provided with its own switching circuit, audio monitor Line 1—Line 2. When the audio has been switched to the theater sound circuit, the normal monitor speaker will be in operation. Figure 10 shows the signal selector unit and the pushbutton controls are clearly identified with their respective functions.

The control panel is the focal point of the operation and to fill the requirement of ease of operation, the controls were kept to the bare essentials. The panel contains: (1) the a-c control elements, the power and high-voltage on–off switch buttons; (2) a 3-in. oscilloscope for level setting; (3) a meter to indicate operation of the high-voltage supply and kinescope; (4) the operating controls for the video and audio; and (5) interlock indicator.

For the operation of the equipment the functions of the control are shown in Fig. 11, with each control marked. To place the equipment in operation, it is only necessary to apply power by the power-on button; then to connect the equipment to the incoming signal and perform checks which are possible through the operation of the signal selector in conjunction with the monitor and oscilloscope.

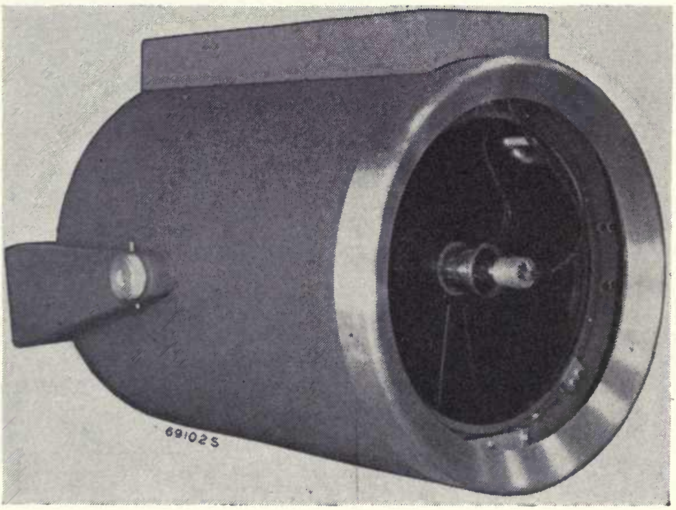

Fig. 13. Projector.

Figure 12 shows the projection booth equipment consisting of the projector control rack on the right and the monitor rack on the left. The units of equipment from top to bottom are: the projector control, the signal selector, the horizontal deflection amplifier, the 300-v regulator, and the high-voltage control panel. The picture monitor is the top unit in its rack; below the receiver for off-the-air reception, the vertical deflection amplifier, the 400-v, 400-ma power supply and the 400-v, 800-ma power supply. Several of the units of this equipment have not been described because of their conventional design.

The projector is shown in Fig. 13, an external view of the completed unit ready for installation on the theater balcony face.

Theater television as an entertainment medium has now reached the stage where a practical commercial equipment has been produced. To date, nine installations of the PT–100 equipment are in operation. The problems now lie with the industry in the field application: the best way to transmit the program to the theater, the type of programming best suited for this new medium, and, most important in the long view, how will picture quality best be maintained from the program subject through the long chain of electronic events before the picture image is viewed on the theater screen? Every effort, in the design of the PT–100 equipment, has been concentrated on building a quality product engineered for present-day use, and providing for standards which may be expected in the future as the needs of the industry are crystallized through the SMPTE.

Bibliography

I. G. Maloff and D. W. Epstein, "Reflective optics in projection television," *Electronics*, vol. 17, pp. 98–105, Dec. 1944.

O. H. Schade, "Electrooptical characteristics of television systems," *RCA Rev.*, vol. 9, nos. 1–4, pp. 5–37, 245–286, 490–530 and 653–686; Mar., June, Sept. and Dec. 1948.

I. G. Maloff, "Optical problems in large-screen television," *Jour. SMPE*, vol. 51, pp. 30–36, July 1948.

R. V. Little, Jr., "Developments in large-screen television," *Jour. SMPE*, vol. 51, pp. 37–42, July 1948.

Projection Kinescope 7NP4 for Theater Television

By L. E. Swedlund and C. W. Thierfelder

The paper describes the design and development of the 7NP4, a 7-in., 80-kv kinescope which is capable of providing clear, bright, theater-size (15 × 20 ft) television pictures. The development involved solving design problems including: (1) a high-efficiency, low-color-shift, white fluorescent screen; (2) adequate high-voltage insulation; and (3) a gun to provide electrostatic focus of a high-current beam into a small, sharp spot, and magnetic deflection through a relatively narrow angle to conserve deflection power and provide essentially uniform focus over the entire picture area.

The 7NP4 is a high-voltage, projection-type kinescope which provides a large, clear, theater-size picture when operated with a suitable reflective optical system. The primary goal in the design of this kinescope was to provide a very bright fluorescent image of adequate resolution and contrast. In order to obtain an optimum design, virtually every element of the kinescope was investigated and improved.

At the beginning of the development of projection-type television in 1930, the light output from fluorescent screens was far from adequate for large projected pictures, even with low resolution standards. Consequently, methods other than direct projection from cathode-ray tubes having fluorescent screens were investigated. These alternative methods fall into two classes: one using a cathode-ray tube having an incandescent or "cando-luminescent" screen, the other using a light-valve type of tube.[1] The former proved to be less efficient in producing light output than a fluorescent screen and also much more subject to overload damage. More success was attained with the light-valve method. This system depends on building up a temporary transparency that is intensely illuminated by a source of continuous light and is projected on the viewing screen with a lens. In general, both designs suffer from low optical efficiency, low resolution and low contrast. The use of intermediate film, which also can be classed as a light-valve method, is perhaps the most successful of the group. Compared to

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Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by L. E. Swedlund and C. W. Thierfelder, Tube Dept., Radio Corporation of America, Lancaster, Pa.

direct projection from a kinescope having a fluorescent screen, the use of intermediate film has the disadvantages of time delay before projection, loss of resolution, the need for additional specialized operating personnel, and the high cost of film and processing. It has advantages, however, in that it can use standard movie projectors and provide a record for repeated showings.

Optical projection of cathode-ray tube luminescent images received attention from the advent of cathode-ray tube television, but initially the low tube-screen brightness, combined with low-efficiency optical systems, resulted in very dim images, even on small screens. The development of the Schmidt camera lens for cathode-ray tube projection,[2] giving an approximately fivefold gain in optical efficiency over the best refractive optical system, marked a considerable advance toward the realization of theater-size television pictures. In 1941, a system of this type, utilizing a 7½-in. kinescope operating at 65 kv, was demonstrated in New York City.[3] This development was interrupted by the war, but since its resumption, continuous progress has been made, not only in increasing light output, but also in improving quality, reliability and tube life.

Light-Output Factors

The light output of a luminescent screen in a kinescope depends primarily on the energy of the electron beam and the light-conversion efficiency of the screen. The electron energy per unit time is the product of beam voltage and current. The maximum value of beam current at a given beam voltage is determined by the rate at which the energy of the electron beam can be absorbed by the phosphor, and by the maximum current which can be sharply focused by the electron gun. As a result, the beam current is limited to a few milliamperes. The principal means of increasing the energy, therefore, is to raise the beam voltage. In addition to increasing the energy of the electron beam, a higher beam voltage improves the light-conversion efficiency of the luminescent screen and permits a higher-current electron beam to be sharply focused by the electron gun. Maximum light output, therefore, increases with voltage at a greater rate than indicated by a linear relationship between the two. Raising the voltage, however, makes necessary the provision of better insulation and higher deflection energy; hence a voltage limit is introduced which depends on how well these requirements can be met.

The efficiency of the conversion of electron beam energy into visible light is determined chiefly by the choice of materials used in the fluorescent screen. The density of the electron beam striking these materials is also a factor influencing the efficiency.

High light output from the 7NP4 is obtained chiefly by using a high-efficiency screen and an 80-kv anode potential.

Size of 7NP4 Screen

The light output of a projection kinescope can be increased somewhat if the size of the luminescent screen is increased. This method of raising the light output is of secondary importance, however, and is limited by the desirable and practical bulk and cost of the optical system.

The increase in light output with increasing screen size is made possible by the attainment of higher conversion efficiency. The factors responsible for the variation of efficiency with varying screen size are: (1) the current density saturation of the luminescent screen material and (2) the temperature of the screen. The larger focused spot on a larger screen results in lower current density and hence in less saturation. The greater cooling surface and lower

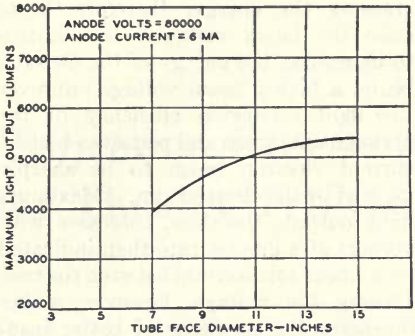


Fig. 1. Variation of maximum light output with changing screen size.

power density permit operation at a lower screen temperature. Figure 1 shows the variation in peak light output with screen size.

Although an increase in screen dimensions does permit some increase in light-conversion efficiency, it does not permit appreciable increase in beam energy. It might seem that the use of a larger screen, by permitting the employment of a larger spot for the same resolution, would permit the use of a higher beam current. But this is not so. Even when beam current is held constant, the spot size increases practically in proportion with screen size, for a given deflecting angle and beam voltage. Therefore, an increase in current would enlarge the spot size beyond the limit imposed by the requirement for good resolution.

In spite of the fact that a larger screen results in somewhat greater light output, the size, weight and cost of the optical system increase so rapidly with increasing screen diameter that practical considerations limit the size of the screen. The volume and weight of the optical system are approximately proportional to the cube of the kinescope diameter, and the cost of the optical system increases approximately as the square of the kinescope diameter. • Projection kinescopes with diameters of up to 15 in. have been experimentally made and tested. It is found that a kinescope with a faceplate diameter of 7 in. gives a good balance between the light output and the bulk and cost of the reflective projector.

Screen Materials

A luminescent screen with a high efficiency in converting the electron beam energy into light was one of the goals in the development of the 7NP4. Sulfide-type phosphors are normally the most efficient, but, because of current-saturation effects, their efficiency is inferior at the high current density used in a projection tube. Silicate-type phosphors are less efficient at low current densities but, because they undergo less saturation, their over-all efficiency in a projection tube is greater. They are, therefore, preferred for this application. There are relatively efficient silicates which emit in the yellow-orange spectrum, but unfortunately the blue-emitting silicate has rather low efficiency, although it has even less current saturation than the yellow-emitting material. If the screen is composed of a mixture of yellow-emitting silicate and blue-emitting sulfide, the efficiency will be relatively high but the color will shift toward the yellow as the current density is increased. This color shift is objectionable but can be reduced by settling the sulfide against the glass faceplate and the silicate in a layer next to it, exposed to the incident electron beam. Then, since the beam is partly absorbed and diffused while it is penetrating the silicate layer, the current density is lower when the beam reaches the sulfide. But even with the reduction in current density due to the relatively thick layer of screen material required for efficient high-voltage operation, the color shift is still objectionable. The color shift was finally reduced to a negligible value by the substitution of blue-emitting silicate-type

phosphor for part of the blue-emitting sulfide phosphor.

The optimum screen weight for the 7NP4 is approximately 8 mg of phosphor material per square centimeter. This value is about three times as great as that used in a low-voltage kinescope of the directly-viewed type. An important feature is the aluminum surface applied to the back of the screen to maintain it at full operating potential and to reflect light from the back to the front.[4]

Insulation Considerations

In the projection tube the external high-potential and low-potential terminals cannot be separated by the full length of the tube, as is done in X-ray tubes. A deflecting yoke which is approximately at cathode potential is fitted over the projection tube neck, near the midsection of the tube. Therefore, the full anode potential is applied over half the tube length. The yoke is grounded and the cathode should be operated at or near ground, rather than negative to ground as in X-ray tubes, in order to facilitate the design and production of equipment using the 7NP4.

Adequate air insulation is obtained for the projection tube by placing the anode terminal as near the face of the tube as possible and by selecting a narrow deflection angle to make the cone long. The surface leakage path is increased by molding circumferential corrugations in the cone section of the bulb. In order to avoid the formation of a film of moisture on the glass, which tends to promote corona and arcing, the cone is coated with a moisture-repellent, insulating lacquer coating. This coating is colored black to help reduce stray light reflections in the optical barrel (Fig. 2).

The air space between the yoke and the neck may be another source of corona and breakdown because it is a dielectric in series with the glass neck, and the full anode voltage is applied across the two. Due to the fact that the air has a much lower dielectric constant than the glass, it is subjected to a higher voltage stress and may break down. Such breakdown would result in corona, heating and possible failure of the glass insulation. This voltage stress is avoided by applying a conducting lacquer to this part of the neck and connecting it to ground.

Fig. 2. Photograph of 7NP4 kinescope.

Internally the cone is at anode potential from the luminescent screen to the anode end of the electron gun (Fig. 3).

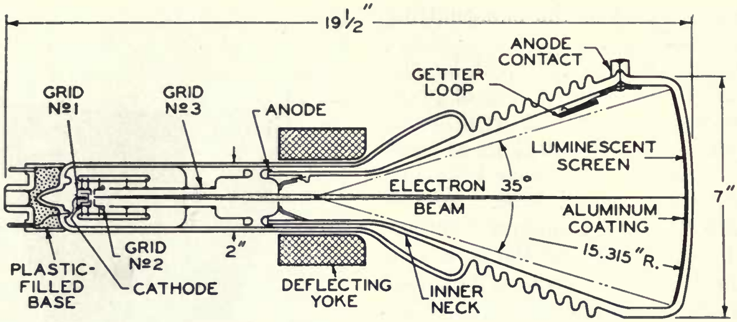


Fig. 3. Cross section of 7NP4 kinescope.

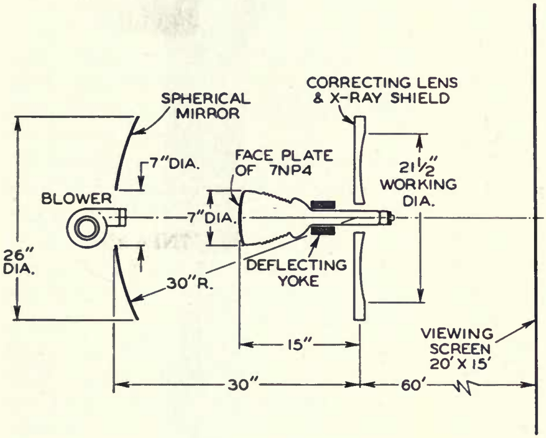


Fig. 4. Typical optical and cooling system for theater - television projector using 7NP4 kinescope.

Thus, the full anode voltage is applied between the outer conducting lacquer and the inside of the neck under the yoke. In a conventional design, therefore, the glass wall of the neck of the tube would be stressed by the full 80-kv potential difference. But it is difficult to make a glass wall uniform enough to withstand more than 40 kv. The insulation problem posed by this property of glass was solved by D. W. Epstein who placed a second, larger neck around the portion of the neck carrying the high anode voltage and provided vacuum insulation between the two necks.

Another insulation problem was to provide an external terminal for the focusing electrode, which operates at 17 kv. A first attempt at solving this problem was made by sealing a terminal in the glass neck. This terminal, however, had to be flush with the surface in order to provide clearance for the yoke. A better method of making contact was sought in order to obtain a trouble-free connection and to facilitate insertion and removal of the tube from the projector. After various materials and structures for the stem leads and base insulation were investigated, it was found that if a plastic material having high dielectric strength replaced the air in the space inside the base, the

focusing voltage connection could be made through the base. A novel procedure developed for producing this structure consists of filling the base with an exothermic plastic mixture and polymerizing it in place. The plastic also serves to cement the base to the neck.

Faceplate Considerations

The faceplate of the 7NP4 projection kinescope is designed to be used in a Schmidt-type reflective optical system (Fig. 4) and as such has to be a precision optical element accurately aligned with the rest of the system. The faceplate is a spherical section with a radius of curvature of 15.315 in. as required by the design of the optical system. It is not difficult to grind and polish the faceplate glass to the desired optical tolerance, but unless special techniques are used when it is being sealed to the cone of the bulb, it is distorted much more than can be tolerated. It was found desirable to grind the glass to a radius of curvature slightly greater than that required by the optical system and to allow the radius to decrease during the controlled sealing and glass-annealing operations. The glass face is accurately aligned with the bulb neck in order to minimize the amount of adjustment needed in the projector.

It has been known for many years that glass darkens when subjected to high-voltage electron and X-ray bombardment. This phenomenon is readily observed in X-ray tubes, but it is not objectionable there because it does not affect X-ray transmission. The color of the darkening is usually a yellowish brown and its intensity varies considerably with the glass composition. The soft glasses, such as ordinary window glass, darken much more quickly than the hard or borosilicate glasses and cannot be cleared or bleached appreciably by heating as can many of the latter types. The darkening appears to be due partly to electron bombardment of the glass, which affects the surface, and partly to X-ray bombardment, which produces a darkening that extends into the body of the glass. The darkening caused by X-rays can be bleached by heating the glass to about 200° C with infrared radiation.

Corning Type 774 Pyrex glass, a hard glass commonly used for laboratory and high-voltage glassware, darkens objectionably in about 50 hr of operation when used in an 80-kv theater-projection kinescope. Extensive tests over a long period of time were run in cooperation with the glass companies to find or develop a glass which would evidence little or no darkening. Although a few were found, they had other characteristics which made them unsuitable. Finally, methods were devised for overcoming the optical deficiencies of one of these types having little darkening, and this glass, Corning Type 707, was chosen for the 7NP4. This glass is a low thermal-expansion, hard glass, originally developed to have good high-voltage and electrical loss characteristics. Until recently, however, this glass had not been produced with satisfactory optical quality. But when special care is exercised and larger melts are made, 707 glass of relatively good optical quality is obtainable. A few seeds or small bubbles have to be tolerated but the faceplates are selected so that these blemishes are not near the inside surface. Because the optical system has a very shallow depth of focus, these imperfections are not noticeable in the image. This glass does darken gradually, but it can be bleached by heating with infrared radiation lamps for about 20 min as shown in Fig. 5. This treatment should not be needed before about 150 hr of operation.

Electron Gun Considerations

The electron gun must project a very intense electron image on the luminescent screen. The spot diameter at maximum current should not be much

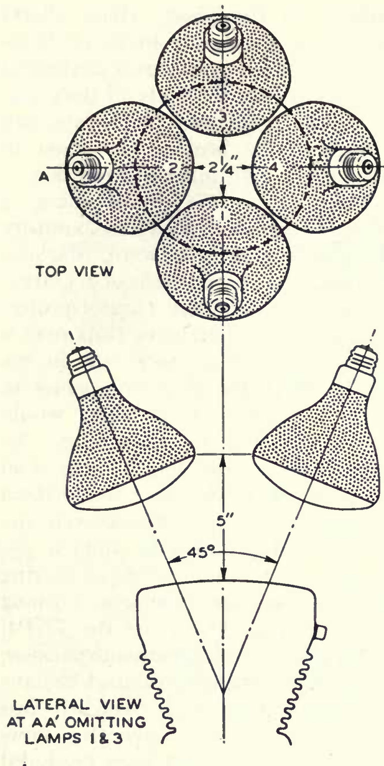


Fig. 5. Arrangement of infrared lamps for bleaching 7NP4 faceplate.

larger than the line width of a 525-line image on this tube (7.5 mils). The spot size will decrease with current, a tendency which helps to improve shadow detail. Because, on the other hand, deflection acts to increase spot size, some allowance has to be made for this effect. The electron beam can be focused either with an external magnetic field or an internal electrostatic field. With good design, both systems can be made to function with negligible aberration; the choice, therefore, can be made on the basis of ease of manufacture and ease of mounting and operating the tube.

In a reflective optical system, the kinescope and its accessories block out reflected light. For this type of application, therefore, electrostatic focusing is preferable because it results in more compact kinescope accessories and removes the problem of providing support and adjustments for a relatively heavy magnetic focusing coil. Electrostatic focusing voltage may be obtained from a bleeder resistance across part of the anode-voltage supply. This method is advantageous because it provides automatic correction of focus. As the brightness of the image varies, the load on the voltage-anode supply changes, causing the voltage applied to the focusing electrode to vary. A change in focusing-electrode voltage occasioned, for instance, by a switch from a dark to a bright picture, results in a change of focus such that a sharp picture is maintained. In contrast, with magnetic focus the focusing field is manually adjusted and is not readily controlled automatically because of the inductance of the focusing coil.

A further reason for using electrostatic focusing in the 7NP4 is that this type of focusing reduces an insulation problem. The voltage across the gap between the anode and the adjacent focusing electrode is about 63 kv. With magnetic focusing, the voltage across the gap between anode and the adjacent point of the electron gun would be 80 kv. An additional advantage is that, when the RCA 5890, a new high-voltage regulator tube, is used, one may adjust the focusing voltage with a low-voltage, low-current, remote-control potentiometer. A disadvantage of electrostatic focus compared with magnetic focus is that it increases the difficulty of tube manufacture, because the gun is a little more complex. Nearly perfectly circular electrodes must be provided to produce the symmetrical focusing field required for a round spot.

The electron gun in this tube has an oxide-coated cathode. The voltage rating of the gun is probably higher than that of any other vacuum-tube unit

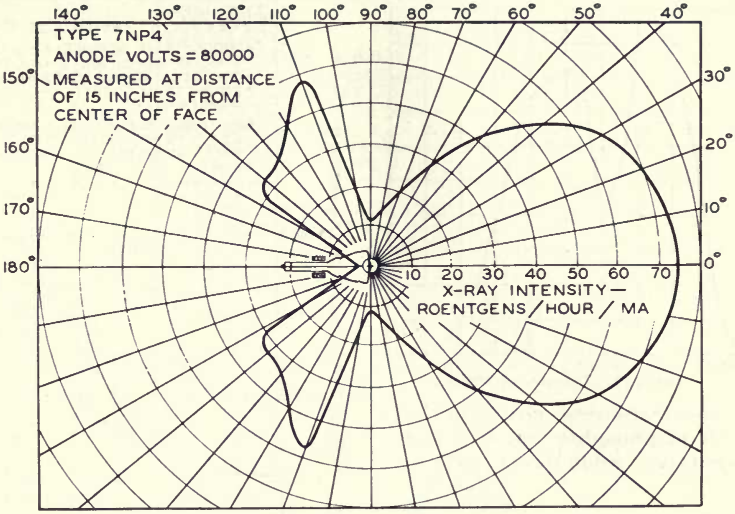


Fig. 6. Polar distribution of X-Ray radiation from 7NP4.

with an oxide-coated cathode. An oxide-coated cathode is desirable because its high emission permits formation of a high-current-density beam and thus helps provide sharp focus. Furthermore its low work function greatly reduces the control voltage required. Reliable operation of an oxide-coated cathode at very high voltage is made possible by means of excellent exhaust and getter systems which produce and maintain a very low gas pressure and limit ion bombardment of the cathode surface. The getter is flashed over the entire inside surface of the cone, providing a relatively large active area close to the main sources of ionized gas molecules. A getter flash over the inside of the bulb is possible because the aluminum screen backing protects the luminescent screen and because a deposit of getter on the screen does not appreciably reduce the energy of the high-voltage beam.

Deflection Considerations

Magnetic, rather than electrostatic, deflection is always used for high-voltage cathode-ray tubes to avoid insulation and distortion problems inherent with the latter.

A smaller deflection angle than that used in kinescopes for home-television receivers was chosen for the 7NP4 in order to reduce deflection-power requirements and to minimize loss of edge resolution. The larger-diameter neck required for the double-neck insulation makes deflection more difficult because the length of the deflecting yoke field is determined by the clearance of the inside neck. The deflecting power needed is of reasonable proportion, however, being not much greater than that required for wide deflection-angle, home-television receivers. A good margin of deflection power for reliability and good linearity is, therefore, readily provided. A narrow deflection angle also requires an increase in the distance between the electron gun and the screen. The increase in distance increases spot magnification, but this effect is compensated for by making the electron gun longer.

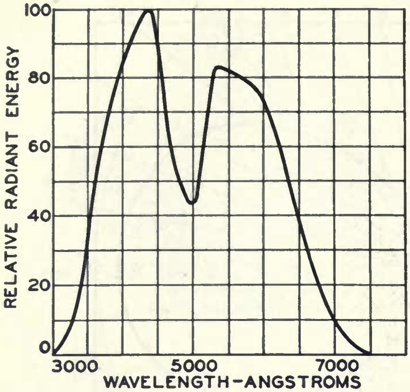


Fig. 7. Spectral-energy emission characteristic of phosphor No. 4, silicate-sulfide type; color temp., 6300 K.

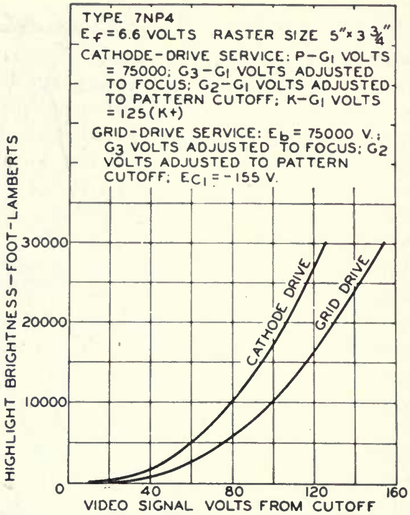


Fig. 8. Average drive characteristics of 7NP4.

Application and Operation

The 7NP4 operates at a voltage which produces penetrating X-rays. The radiation is emitted in a pattern that is symmetrical about the tube axis, as shown in Fig. 6. The X-ray intensity indicated is representative of normal operation. Although this level is low compared to that of a commercial X-ray tube, it is several thousand times the safe level for continuous exposure at close range. Sufficient shielding can readily be provided by enclosing the optical system in a metal barrel. Because radiation may extend for several feet in front of the projector, an X-ray-absorbing window may be needed.

The screen emits white light which has an equivalent black-body color temperature of approximately 6300 K. The spectral distribution of the energy emitted by the screen is shown in Fig. 7. At peak light output the maximum power input to the screen is approximately 480 w. For this condition the peak power in the beam is approximately 1000 kw/sq cm. This power density is extremely high and it is only because the spot moves across the screen at high velocity that the screen is not destroyed. Hence it is extremely important to provide full scanning at all times when the beam is on.

The faceplate of the 7NP4 is an optical component and has to be accurately positioned in the optical system. The high-voltage anode terminal is near the faceplate, so a support here to position the faceplate would require full anode-voltage insulation. The deflecting yoke is at ground potential and is thus a more convenient place to support this tube. Due to the method of assembly of the glass bulb parts, the neck is well aligned with the faceplate, but lateral as well as longitudinal adjustments are needed to position and focus the luminescent screen properly in the optical system.

In normal operation 80 to 160 w may be dissipated at the screen. With only radiation and convection cooling, this dissipated power would produce an excessive temperature and thus reduce the efficiency of the luminescent screen and possibly fracture the glass. A stream of air from a small blower, directed perpendicularly at the faceplate through a hole in the center of the mirror, is sufficient to keep the glass temperature

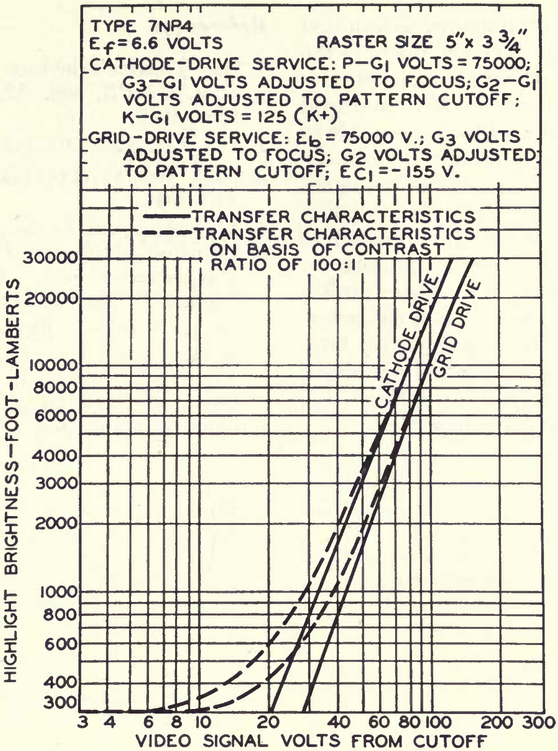


Fig. 9. Average drive characteristics of 7NP4 in log–log coordinates.

below 100 C, the recommended maximum temperature for the outside of the face glass. The cooling air should be filtered to eliminate dust and minimize moisture formation inside the optical barrel.

Because of the relatively high beam current desired, an average grid-drive voltage of 155 v is needed. Inasmuch as a generous video bandwidth is needed to produce good detail, it is desirable to reduce this voltage requirement if possible. A worth-while gain is obtained by applying the video signal to the cathode instead of to grid No. 1. For example, with grid No. 1 grounded and the signal applied to drive the cathode negative, the grid No. 1-to-cathode voltage decreases and in addition, the grid No. 2-to-cathode voltage increases (Fig. 8). Both actions increase the beam current. The signal required is thereby reduced to 125 v by the compound action of the drive voltage.

Figure 9 shows the transfer characteristics on a log–log graph in the form used to indicate photographic film characteristics. This form of presentation has been described by O. H. Schade.[5] The transfer characteristic is obtained by measuring the brightness of an unmodulated raster. In an actual picture some light is scattered into the black areas. This effect will vary with the type of picture, but 1% of scattering is a representative value. The result is a contrast ratio of 100:1 in the luminescent screen. A second transfer characteristic, taking this reduction of con-

trast into account, is shown as a dotted line. The slope or gamma of the straight part of these characteristics is 2.4 and 2.6 for cathode drive and grid drive, respectively. It is not possible to vary this slope appreciably by gun design changes. The gamma of the signal can be modified in the video amplifier and, of course, should be adjusted to provide the desired over-all gamma.

The expected life of a theater projection kinescope is an important characteristic. Although there is relatively little actual operating experience, simulated life tests indicate that an average life expectancy of 500 hr is possible.

References

1. See "Theater Television Bibliography," *Jour. SMPE*, vol. 52, pp. 268–272, Mar. 1949.
2. U.S. Pat. 2,273,801, Feb. 17, 1942.
3. *RCA Rev.*, vol. 6, no. 1, pp. 5–11, July 1941.
4. W. Epstein and L. Pensak, "Improved cathode-ray tubes with metal backed luminescent screens," *RCA Rev.*, vol. 7, pp. 5–11, Mar. 1946.
5. O. H. Schade, "Electrooptical characteristics of television systems," *RCA Rev.*, vol. 9, nos. 1–4, pp. 5–37, 245–286, 490–530 and 653–686; Mar., June, Sept. and Dec. 1948.

Installation of Theater Television Equipment

By E. Stanko and C. Y. Keen

Recent initial installations of the RCA PT-100 Theater Television System are described. Problems encountered in these installations and their practical solution are discussed. Now that the first commercial Theater Television Systems have been installed in a number of representative theaters, the experience acquired at these installations will be valuable in reducing the installation of theater television equipment to a routine procedure, comparable to the installation of sound motion picture equipment. Procedures followed in making these initial installations are described, beginning with the preliminary theater survey to the final installation check and adjustment before projecting a picture on the screen, including service and maintenance problems.

Preliminary Theater Survey

Before an installation of theater television equipment is made in any theater, certain facts about the theater must be known. One of the most important items to be determined by the survey is the location of the equipment, especially the projector unit. The PT–100 System Projector employs a Schmidt-Type Optical System with a correction lens which is limited in projection "throw" to a definite operating range.

Figure 1 shows the operating range of the optical system. There are three variables:

1. Picture size,
2. Kinescope raster* size, and
3. Projection throw from projector to screen.

So far all of the initial installations have been made in balcony-type theaters, where the projector is mounted at the front face of the balcony or in the front part of the balcony structure.

The preliminary survey includes an elevation outline plan of the theater with dimensions so that the three variables shown on the chart can be resolved and the position of the projector and screen and screen size, determined.

Theater plans are obtained where possible and are carefully examined so that the theater exhibitor can be advised how to proceed with the installation.

The survey also determines the location of the control racks in the projection booth and the location of the 80-kv high-voltage power supply unit, and includes information that will be required to solve any unusual problems in connection with the installation of the equipment.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N. Y., by E. Stanko and C. Y. Keen, RCA Service Co., Inc., Camden, N. J.

**Raster* is defined as the illumination caused by the scanning lines on the cathode-ray screen when no television picture signal is being received. Picture size is slightly smaller due to blanking interval.

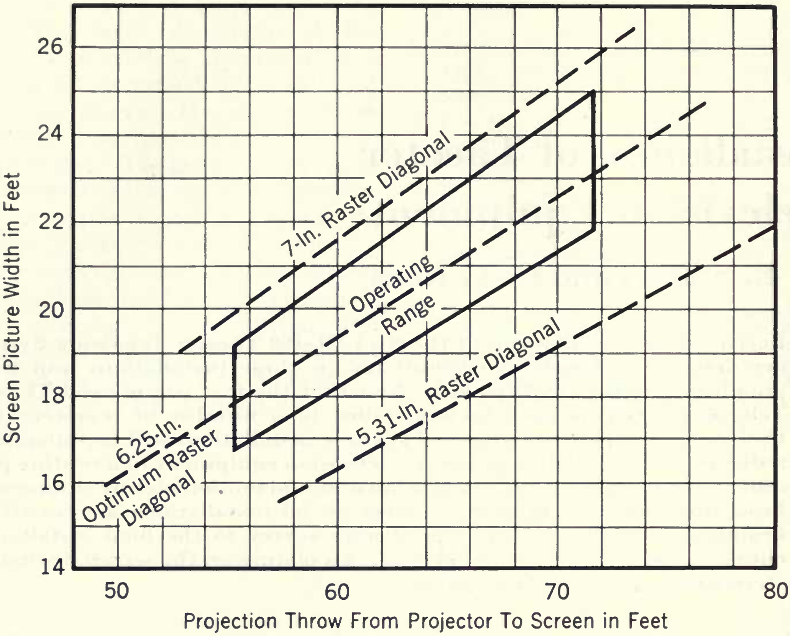


Figure 1.

Antenna Surveys

There are several means for bringing a television program to the theater. Video line facilities, consisting of coaxial cable or an equalized pair, is one method. Point-to-point transmission by microwave relay equipment is another method. "Off-the-air" pickup on the present television channels is still another method.

The PT–100 equipment is designed to receive programs by any one or all of these methods.

If "off-the-air" pickup is a requirement, it may necessitate special antenna facilities. In this case, at the request of the theater exhibitor, an antenna survey is made with the use of field-measuring equipment to determine the possibilities of obtaining an acceptable "off-the-air" signal and prepare installation instructions and specifications for an antenna installation suitable for an electrical contractor to use in order to insure getting the best possible signal obtainable at the theater location. "Off-the-air" program pickup is not generally considered to be an entirely satisfactory means of providing theater television programs, as the picture quality obtainable is, in most cases, below the performance possible with the PT–100 equipment. Figure 2 shows an antenna survey crew ready to make a field strength survey.

Installation of the PT–100 Equipment

Installation of this equipment can be divided into five principal operations. (Figure 3 shows the PT–100 Exhibitors Installation Instructions.)

1. Installation of the projector,
2. Installation of projection-booth rack equipment,
3. Installation of the high-voltage supply unit,
4. Electrical connection of equipment units,
5. Hanging the screen.

Installation of the Projector (*Figs. 4–8*).

The PT–100 System Projector is supported on legs at its center of gravity and can be pivoted in a vertical direction ±10°. Four bolts are used in each supporting leg to secure the projector to a supporting plate or steel structure which must be provided by the theater. The projector weighs 400 lb. The location of the projector, as determined by the preliminary theater survey and the construction of the theater, will determine how it is to be mounted.

In several of the initial installations of this equipment the projector was mounted with the legs horizontal. Several other installations were made with the legs mounted vertically. The method of mounting will vary in different theaters although some degree of standardized practice may be evolved from the experience gained with the first installations.

If the projector is mounted on the front face of the balcony it will require a supporting steel framework secured to the balcony steel structure with a flat surface to which the legs are bolted.

When the legs are mounted in the horizontal position, care must be taken to be sure that the supporting structure allows for some adjustment in the horizontal plane to insure that the optical axis of the projector is centered on the screen which is centered with the theater center line.

If the projector is mounted with the legs vertical it is usually easier to adjust it so that the optical axis is centered.

One method of mounting the projector that has some practical advantages utilizes two I beams projecting from the front of the balcony, which are secured to the balcony main I-beam truss and, further back, to the balcony steel structure in a cantilever arrangement.

Fig. 2. An antenna survey crew ready to make a field strength survey.

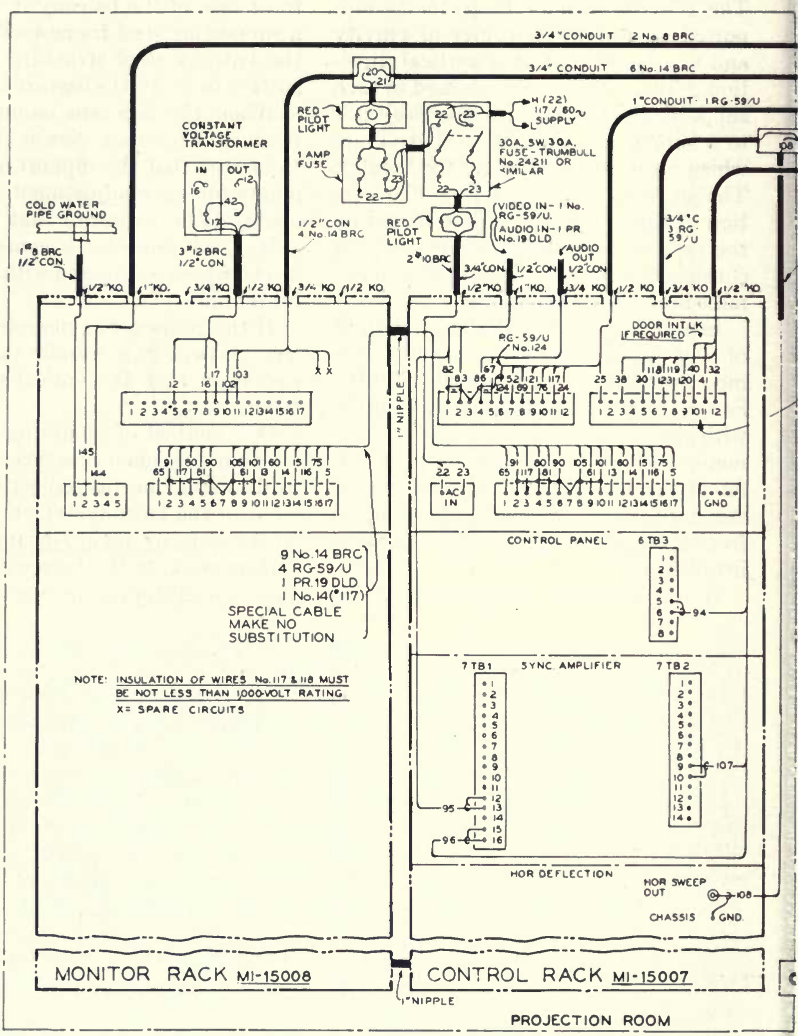
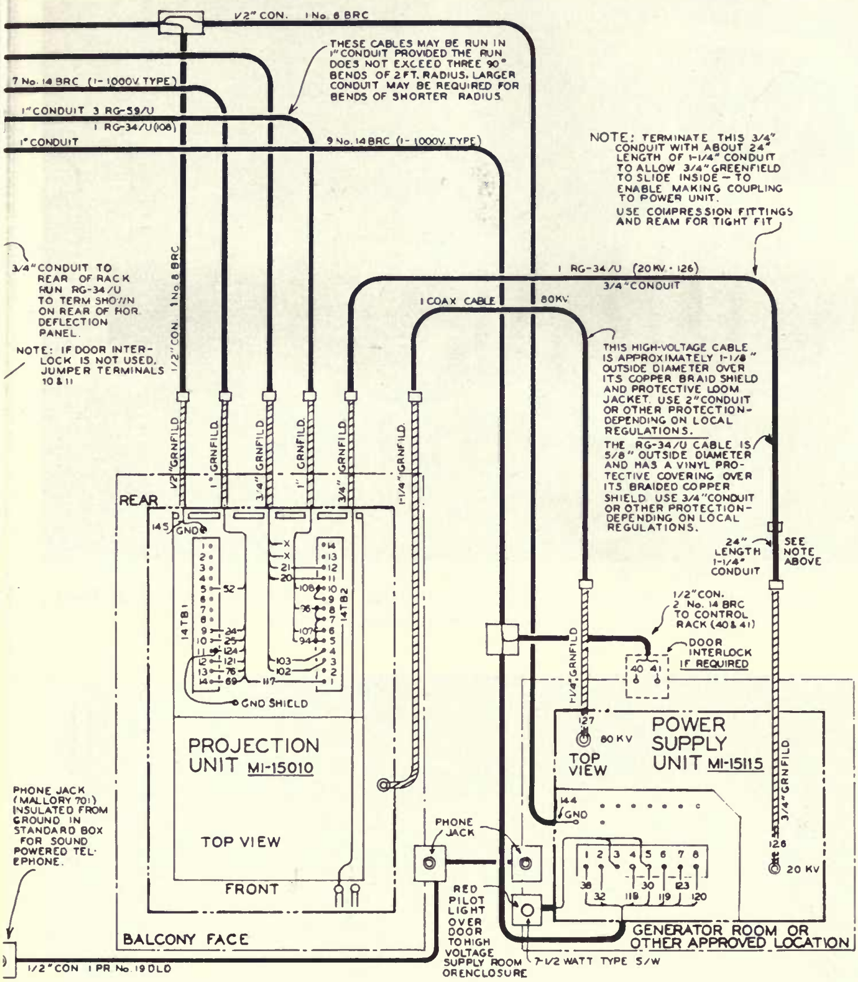


Fig. 3. Exhibitor's installation

The I beams are separated sufficiently to allow the projector legs to be mounted vertically on a plate which is bolted across the bottom of the I beams at the required distance to provide about one foot of space between the rear of the projector and the balcony face.

Provision must be made in any method of mounting so that the mounting structure does not interfere with the high-voltage cable connection to the barrel or the wiring entering the top rear conduit plate.

A servicing platform must be provided on the right side of the projector, the floor of which is on a level with the bottom of the legs when they are in the vertical position.



instructions for the projector.

The projection angle will vary in different theaters but should be kept as small as possible. The screen must be angled to the same degree. A good rule that has been applied to initial installations is to mount the projector as low as possible and the screen as high as possible, consistent with sight lines to the screen from the rear of the orchestra, the mezzanine or balcony, and interference of the projector with these sight lines. This can be determined from the theater plans when the preliminary survey is made.

When the distance from the balcony face to the screen is less than about 55 ft the projector may have to be mounted back two or three rows in the balcony

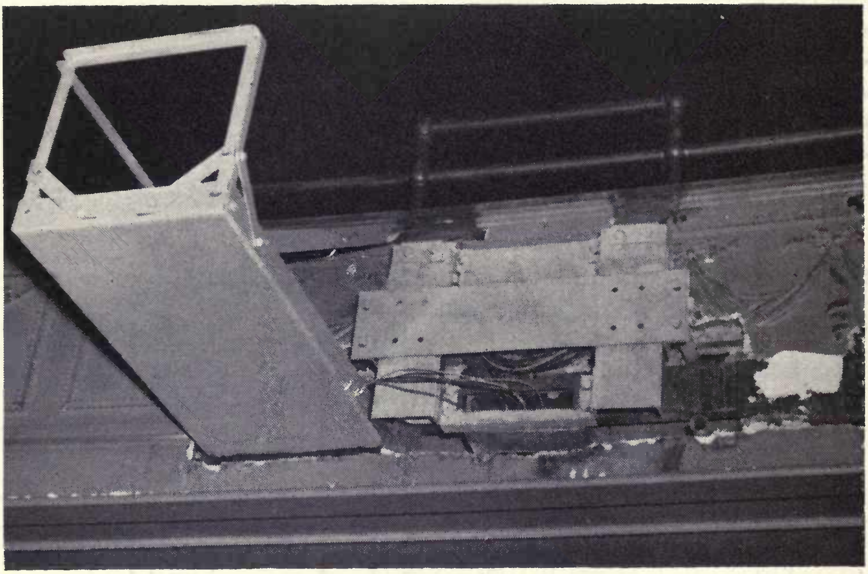


Fig. 4. Steelwork for mounting projector with legs in horizontal position, and service platform.

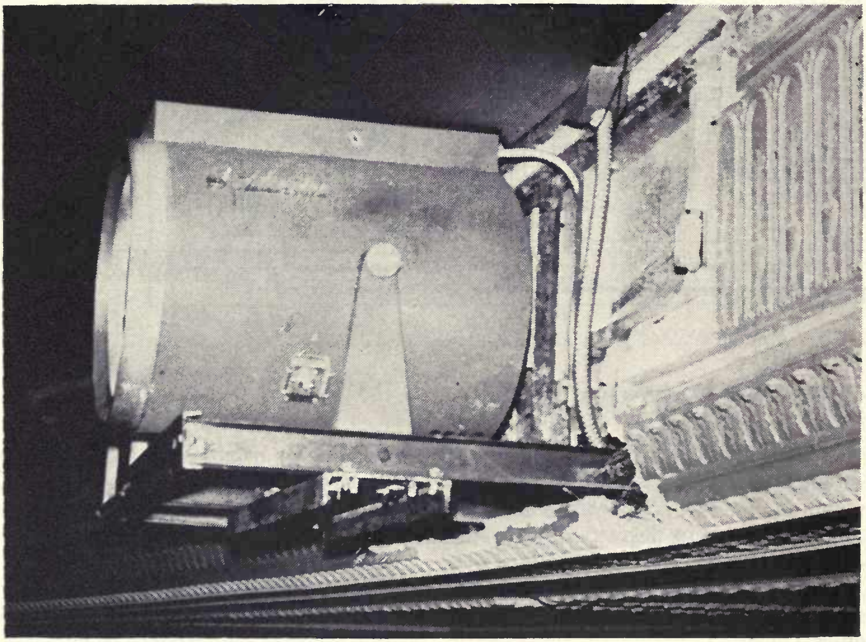


Fig. 5. Projector with legs mounted vertically on balcony steel framework.

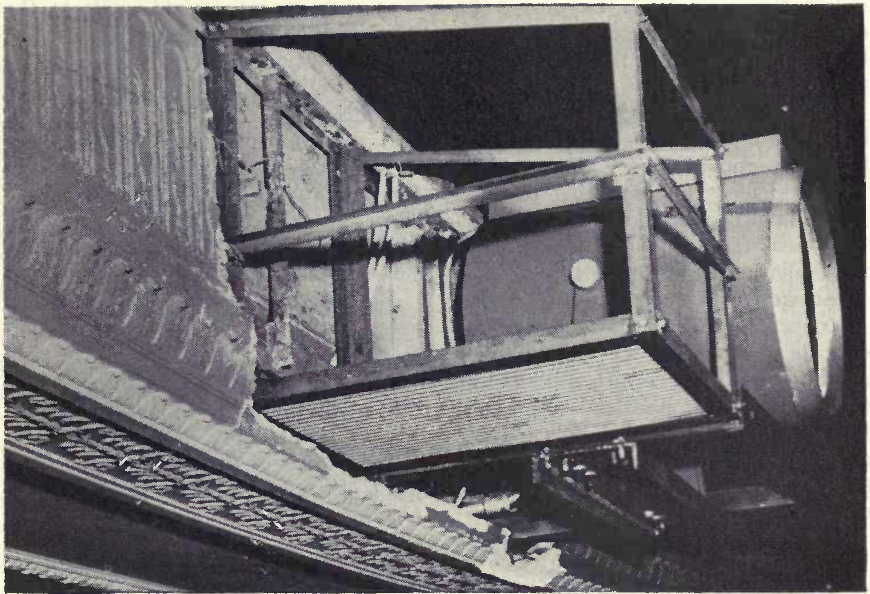


Fig. 6. Projector mounting with service platform, side view.

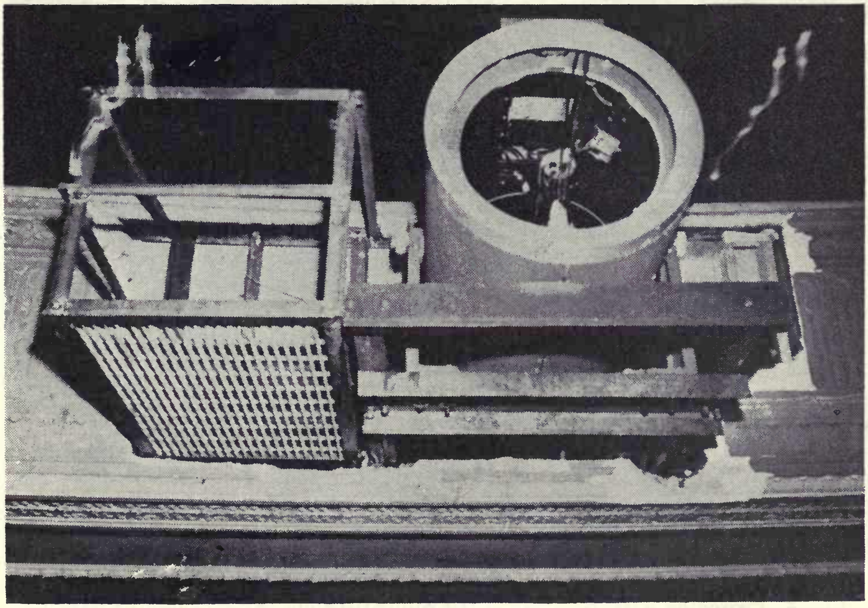


Fig. 7. Projector mounting, front view.

unless the screen can be moved far enough back on the stage to come within the operating range of the projector optical system.

Mounting the projector back in the balcony will probably require some theater constructional changes.

Several ideas for mounting the projector have been proposed for stadium-type theaters, but none have been tried in installations as of this writing.

Installation of Projection Booth Rack Equipment (Fig. 9). The booth equipment consists of two racks 63 in. high which are fastened together with conduit nipples and interconnected electrically through the top conduit nipple. These are similar to sound equipment racks and have conduit knockouts at the top of each rack.

It is desirable to mount the racks so that they are at a right angle to the front wall of the booth and adjacent to an observation port so that the screen can be observed when operating the controls.

A voltage-regulator transformer mounted at some convenient location in the booth or adjacent to the booth, the main power switches, pilot lights and fuse box comprise the balance of the PT–100 System Booth Equipment.

Booth space requirements in a few cases presented the only problem encountered in the installation of the rack equipment. In these instances space was made available by rearrangement of booth equipment.

Installation of the High-Voltage Supply Unit. Some problems have been encountered in the installation of the high-voltage supply unit.

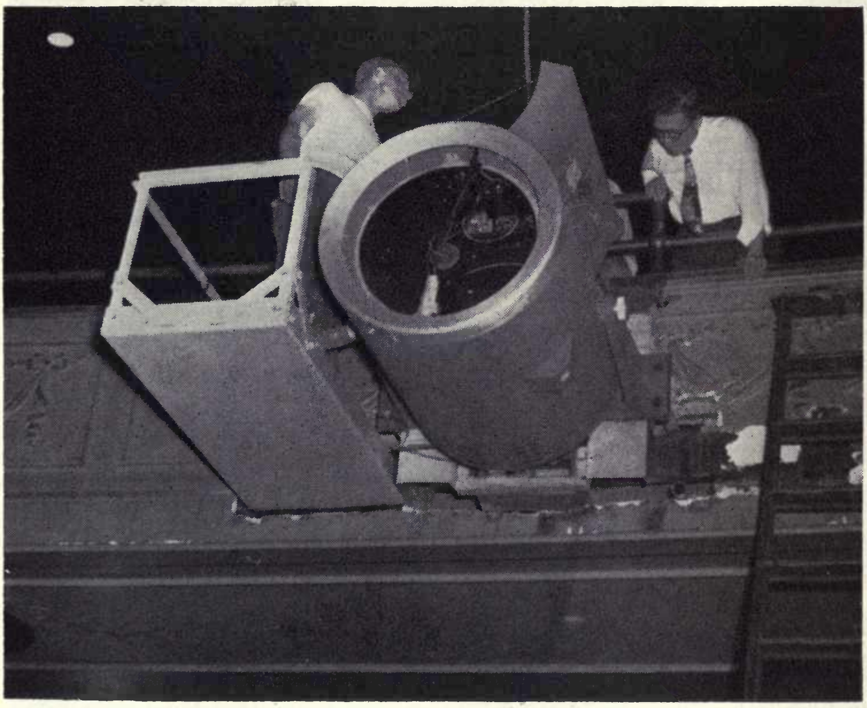


Fig. 8. Projector with horizontal leg mounting showing access to barrel from top.

As yet there is no provision in the National Electrical Code covering the installation of a unit of this type in theaters. Local rulings in several cities have required the unit to be placed in an enclosure separate from the projection booth with a door supplied with an electrical interlock switch which will turn off the supply when opened. Provision for this was anticipated in the equipment design.

Generally, it is desirable to locate this unit as near the projector as practicable to keep the 80-kv cable as short as possible. In some cases it has been located in a space under the balcony. The two high-voltage connectors (80-kv and 20-kv) are made up at the time of installation with a complete kit of materials furnished each installation.

Fig. 9. Installation of Projection Booth Rack Equipment.

A small chain hoist provided by the theater is installed above the high-voltage supply unit to raise the assembly part way out of the oil for service access. The rectifier tubes and voltage-regulator tube are accessible from the top of the unit by raising a smaller part of the assembly making it unnecessary to raise the complete assembly to change tubes.

Electrical Interconnection of Equipment Units. The exhibitor's installation instructions furnished with the PT–100 include a complete wiring diagram with conduit sizes and all details required by an electrician to wire the equipment (see Fig. 3). In many respects the wiring is similar to theater sound equipment and follows established theater practice. The wiring specifications conform to the National Electrical Code wherever it applies. This provision will generally meet all local regulations as well.

Special instructions and assembly drawings are also given in the installation instructions for making up the high-voltage 80-kv connectors and 20-kv connector.

Installation of the Screen. At the present time perforated beaded screens are used for theater television projection, but the ultimate objective is to provide a screen which will satisfy the requirements of theater television and motion picture projection with one screen. Such a screen is in prospect of realization.

The screen must be located to provide a throw distance from the projector which will fall within the operating range of the PT–100 Optical System, as shown on the chart in Fig. 1.

Since practical considerations may require that the projector be located at the face of the balcony, it may be necessary to locate the theater television screen in front of or behind the present motion picture screen to bring the throw within the operating range of the system.

This presents some problems and in a

few cases has required the use of separate speakers for the theater television audio program.

Another problem was posed by the requirement of tilting the screen an amount equal to the projection angle due to the short depth of focus in the extremely "fast" optical system used in the PT–100 system.

These problems have been resolved without much difficulty in installations to date.

The screen must, of course, be masked to provide sharp picture edges. The angle of projection and the tilt of the screen and its location are all calculated in advance of the installation from the data obtained in the preliminary survey.

Installation Check and Operation

A very definite procedure has been established to check and adjust the equipment in an orderly step-by-step routine when the installation is completed and power is ready to be turned on.

This is done by a field engineer who has received previous training and is provided with the required equipment to perform this operation.

One of the important checks made on the equipment prior to installing the 7NP4 Kinescope is a step-by-step procedure to be sure that the kinescope protection circuits are functioning correctly.

When the equipment has been thoroughly checked and all adjustments made, the projectionists are given instructions in operation techniques.

Proper operation of the equipment is not difficult and in many respects parallels operation of a home television receiver. Projectionists have done an excellent job on this in the few locations involved so far.

Recently, a group of projectionists selected by the I.A.T.S.E. from practically every state in the Union were given an intensive course of television instruction in Camden, and all had an opportunity to operate the PT–100 equipment set up especially for the purpose in the RCA Engineering Laboratory Theatre.

Service and Maintenance

In any electronic or mechanical equipment there is always the problem of maintaining performance at certain predetermined standards.

Theater television equipment, due to its complexity in comparison with sound motion picture equipment, requires more attention in several respects to insure optimum performance.

There are over 100 tubes in the PT–100 Theater TV System. The average sound motion picture equipment has only about 20 tubes.

While the PT–100 equipment has been carefully designed for stability of operation consistently over long periods, some service operations must be performed by skilled engineers at periodic intervals to insure consistently top performance.

High voltages applied to the 7NP4 Kinescope could cause serious damage to the tube if the protection circuits did not function properly. These tubes are comparatively expensive, therefore periodic checks must be made in the protection circuits with proper test equipment to be sure that the correct circuit constants are always maintained. Pulse forms and amplitudes must be checked periodically with an oscilloscope suitable for this work and adjustments made if required.

The projector mirror and correction lens X-ray plate combination must be cleaned periodically. This requires careful technique with cleaning solutions developed especially for these surfaces. For example, the cleaning solution used on the mirror cannot be used on the lens surface. Service procedures are being formulated and will soon become routine.

Close coordination between the RCA Theater Equipment Engineering Group, responsible for the development and de-

sign of the PT–100 Equipment and the Technical Products Service Group of the RCA Service Company, resulted in incorporating many features in the equipment to make installation problems less difficult and expensive, and to facilitate service and maintenance operations.

Test Equipment

While many troubles in television equipment can be diagnosed by symptoms appearing on the picture screen, it is generally necessary to use an oscilloscope to trace them down in the suspected circuits.

It is necessary to use an oscilloscope that will give a true picture of the wave forms in any part of the circuits. The Type–58 or –79 Oscilloscope is used by the RCA Field Engineers for this purpose. Some of the less expensive "scopes" which are suitable for home television service work are not suitable for theater television equipment. Usually these less expensive instruments are designed for high sensitivity in the vertical amplifier at the expense of wide band response and they have other deficiencies which rule out their use for theater television equipment although they may be entirely satisfactory for checking home television receivers.

A high-resistance voltmeter is also a requirement. The 165A VoltOhmyst is used for this purpose. An instrument of this type has been found to be essential in checking this equipment.

A portable synchronizing and grating generator for field use is now under development. This instrument will furnish a suitable video signal to test the PT–100 Equipment when other signals are not available. Other test equipment is made available when required.

Discussion

Henry Roger: Did Mr. Stanko say it would be simpler to use rear projection on a translucent screen? I presume that you may get higher field intensity.

Otto H. Schade: I think you are perfectly correct in assuming that that is possible. The normal light gain of a beaded screen is not very high—in the order of 2 or 2½. With a properly designed rear-projection screen of the lens type, you can get gains as high as 15 if the viewing angle from the front isn't too wide. Such screens are very expensive. They have to be made very precise and considerable space must be provided behind the screen for the projection distance. If the theater were laid out for such projection requirements, then it might pay to look into this situation. I think there are some rather early papers in the art. I remember a German paper reporting actual gains of the order of 12—that is, the intensity was 12 times that obtained from a purely diffuse reflecting screen.

Mr. Roger: I believe there is one disadvantage with translucent screens, and that is if the projection is in line with the eye of the observer, you get a hot point; but I believe that this can be overcome by mounting the projector slightly lower.

Mr. Shade: The type of screen which I mentioned as a lens screen avoids that completely. It is a structure of small lenses similar to a Fresnel lens directing all the rays from the sides as well as the center of the screen into a certain angle where the seats are. You can design it so that the intensity distribution in this viewing field is completely uniform. A normal translucent screen has no such means. It acts, for example, like a frosted glass, which has a very definite lobe (like an antenna) producing a hot spot in the center and much lower intensity at the sides. By putting a large condenser lens behind it, you can direct the side rays toward the center and therefore create a small area where the screen brightness is uniform. A lens screen is designed to widen this angle over a wider area without having the loss due to frosting the screen which absorbs light and scatters it vertically as much as horizontally. The lens system can be made to keep the vertical scattering extremely small and thus concentrate the entire light energy into the desired viewing space and in that manner raise the effective brightness. Lens screens can also be designed for front projection, but as I said, a lens screen is very expensive compared to normal low-gain screens.

Standards

Splices for 16-Mm and 8-Mm Film

These Proposed American Standards, developed by the 16-Mm and 8-Mm Motion Pictures Committee, appear on the following pages. They are published here for trial and criticism for a period of ninety days. Please forward any comments to Henry Kogel, Staff Engineer at Society Headquarters, by July 1, 1951.

For many years the standards for splices have shown both a diagonal splice with a 0.070-in. overlap and a straight splice with a 0.100-in. overlap. It is presumed that the diagonal splice was narrower so that it would not encroach on the perforations. These dimentions were specified in Chart 12 of Z22–1930 and repeated in 1941 in Z22.24 and Z22.25. Actually, however, the dimensions of the straight splice were first established in 1924 when 16-mm equipment was introduced. Many thousands of splicers making splices with these dimensions have been manufactured and used. When splicers for 8-mm film were introduced in 1932, the same 0.070-in. and 0.100-in. overlaps for diagonal and straight splices were specified.

For twenty years these dimensions have been retained as new splicers came on the market, even though a great deal of experimental work was being conducted in an effort to improve splices and lengthen their life during projection.

In January, 1944, Subcommittee C of the American Standards Association's Z52 War Committee on Photography and Cinematography was appointed to handle standards relating to 16-mm laboratory practice. One of the first projects of this subcommittee was to specify the type of splice that should be used for 16-mm release prints. The discussion showed that there was little agreement among the laboratories. Some preferred narrower splices because they are less conspicuous on the screen. It was stated that, contrary to former beliefs, wide splices were more susceptible to failure than narrow ones. Several members said that they were using splices that were less than 70-mils wide and had found them quite satisfactory. It was then agreed to make the 0.070-in. overlap a maximum inasmuch as it was desired to secure splices with as small an overlap as possible. It was then decided to write a new standard covering diagonal and straight splices.

Later the title of the proposed standard was changed to limit the splices to processed film because the suitability of the splices for raw stock had not been considered by the committee. The final War Standard, Z52.20–1944, was approved May 29, 1944, by the American Standards Association.

This action resulted in the existence of two standards for straight splices: the original 0.100-in. splice from Z22.24–1941 and Z22.25–1941, and the new 0.070-in. splice in Z52.20–1944. It was realized at the time that careful comparative

tests would eventually be required in order to determine which splice was superior. If it were decided to carry over into peacetime the 0.070-in. splice, it would be necessary to rebuild all the existing tools for amateur splicers, which would involve considerable expense to the industry because of the many splicers for 0.100-in. splices on the market.

Consideration of Dual Standards

The desirability of continuing the two standards for splices was considered when Committee Z22 of the American Standards Association reviewed the War Standards in October, 1945. At this meeting, and at subsequent meetings, the need for having standards for splices was questioned, but the committee decided that such standards were of value to the industry. Eventually, the question was referred by Z22 to the Standards Committee of the Society, and a subcommittee was appointed, under the chairmanship of W. H. Offenhauser, Jr., to review the situation.

Meanwhile, the suggestion had been made that the 0.100-in. splice be designated the amateur splice and that the 0.070-in. be the professional or laboratory standard. This suggestion was discussed by the subcommittee, and it was agreed that the standard should prescribe good commercial practice, as well as a splice that would be practicable for the amateur.

The relative merits of symmetrical versus unsymmetrical splices were also discussed, but it was decided that both diagonal and straight splices would be shown symmetrical with respect to the included perforation. Finally, although it was brought out that the 0.070-in. splice would be difficult for the amateur to perform because of the more precise control of hand scraping required, it was voted that the 0.070-in. straight splice be standardized for a trial of one year. During that period, data would be collected so that a review could be made and a final decision reached.

This decision of the subcommittee was reported to the Standards Committee at a meeting on February 20, 1946. Although one member reported at that time that the narrower splice did not last as long in projection as the 0.100-in. splice, it was decided to publish the standard calling for the narrower splice and to collect more information during the trial period of one year.

When the report on splices was presented to the Society on May 8, 1946, the following test results was submitted to Mr. Offenhauser: Of 45 loops of film, each containing one 0.100-in. and one 0.070-in. splice and run in a projector until one of the splices broke, 40 loops broke first at the 0.070-in. splice and only 5 broke first at the 0.100-in. splice. These tests were run by two different departments of the same company, and included three projectors and splices made by several different operators. A third group ran 6 loops containing two splices of each width. The average life of the 0.070-in. splice was half that of the 0.100-in. splice.

Conclusions of Tests

These conclusions were confirmed later with splices made on an expensive precision splicer of the 0.070-in. type. Seven loops were made with one 0.070-in. precision splice and one 0.100-in. splice. All broke at the 0.070-in. splice first. In most cases, nevertheless, the life of the weaker 0.070-in. splice was probably adequate for either amateur or professional use. Such might not have been the case, however, if an ordinary hand splicer had been employed since most operators have considerable difficulty scraping the narrow splice. Bebecause the strip of film between the perforations and the cut end of the film is only 0.010-in. wide, it is difficult to remove all the emulsion without damaging the film. In addition, shrinkage of

the film reduces this width still further and makes the scraping operation even more difficult.

From the foregoing tests, it is quite apparent that the wide splice was stronger despite its greater resistance to smooth bending of film around loops, rollers and sprockets.

Comments After Publication

The proposal of the subcommittee was published in the July, 1946, JOURNAL. It was simpler than previous standards because nonessential dimensions were omitted. Although only sound film was shown, it was stated that splices for silent film would be the same, A curved splice, included in the War Standard, was dropped because no one expressed interest in it. Comments were invited, particularly on the relative desirability of the 0.070-in. splice compared with the 0.100-in. splice, and on symmetrical versus unsymmetrical splices.

Although the response was rather small, a number of interesting suggestions were offered. The suggestions fell into two distinct groups: first, those concerned with splices made in processing laboratories by professionals, usually in negative or other preprint material; and second, those concerned with splices made in reversal originals or release prints.

Of the first group, a proposal by Joseph V. Noble of DeFrenes & Company Studios called for an invisible 0.016-in. frameline splice in the width of the film devoted to the picture area, with an overlap of 0.079 in. along both edges of the films. In addition, John S. Carroll listed the advantages of the unsymmetrical Griswold "negative" splice, and advocated increasing its width from 0.0625 in. to 0.070 in. for greater strength. He did not recommend it for release prints, however, because of its poorer mechanical properties. G. A. Chambers recalled the successful use of 0.070-in. splices at the Anacostia laboratory and recommended them for laboratories but not for the amateur.

The group favoring the retention of the 0.100-in. overlap was interested primarily in amateur splicing. Their arguments were based on the longer projection life. the greater success that the amateur has in making the 0.100-in. splice, and the large investments in tools for 0.100-in. splicers.

Since the industry did not appear to be ready for the adoption of the standards outlined in the July, 1946, JOURNAL, the Committee on Standards agreed that the original Z22.24 and Z22.25 should be reaffirmed until the situation is clarified. At this point, the problem of standards for splices was referred to the 16-Mm and 8-Mm Motion Pictures Committee.

Work of 16-Mm and 8-Mm Committee

In preparing the drafts submitted herewith, the Committee noted that the old standards did not conform to modern methods of dimensioning. It was suggested, also, that sound and silent films be combined into one standard. As these changes were made, it was discovered that other alterations and additions would be desirable. For example, the splices were redrawn so that they would appear as they do on splicing blocks. Tolerances were added to cover the proper transverse alignment of the perforations and the edges of the films, and the parallelism of the edges of the two films after the splice has been made. Again the question of whether straight splices should be 0.070-in. or 0.100-in. wide was raised. For 8-mm film the 0.100-in. splice was of course preferable. When the title and wording of the 16-mm splice proposal were changed to limit it to release prints, all objections to the 0.100-in. splice were withdrawn.

Drafts of the proposals approved by the 16-Mm and 8-Mm Motion Pictures Committee were submitted to the Stand-

ards Committee in May, 1949, for balloting on the question of publication in the Journal for a ninety-day period of trial and comment. In due course, this ballot was completed favoring publication at an early date. During the course of this balloting, however, various members of the 16- and 8-mm Committee raised the question of whether or not manufacturers of splicers still promoted the sale of equipment to make diagonal splices. Upon investigation, it was found that no manufacturer expects to produce equipment of this type in the future. In the light of this information, it was recommended that the diagonal splice be dropped from the proposal.

Since this was considered to be a major change from the version upon which the Standards Committee originally balloted, the ballot was withdrawn at a meeting of the Standards Committee on February 1, 1950. In subsequent balloting, completed in December, 1950, and January, 1951, the Committee approved publication of these two proposals in their present form for trial and comment.

Erratum:

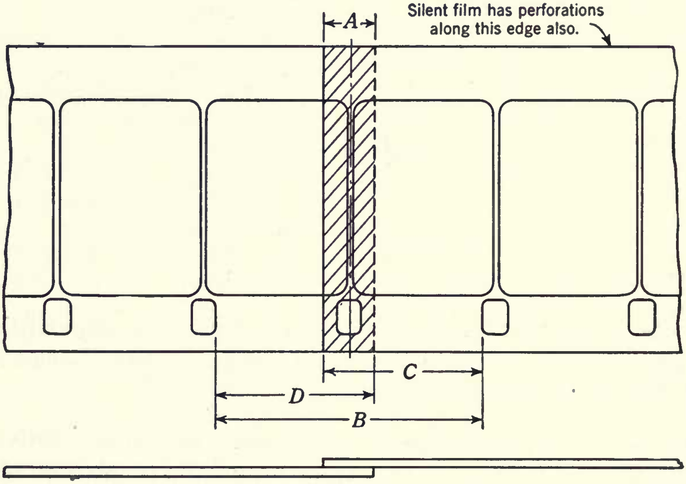
W. F. Kelley and W. V. Wolfe, "Recent studies on standardizing the Dubray-Howell Perforation for universal application," *Jour. SMPTE* vol. 56, pp. 30–38, Jan. 1951.

Page 32, line 5 *et seq.*, and Fig. 1: *For* Cooke *read* Cook. This refers to Allen W. Cook who made the Ansco proposal a number of years ago.

Proposed American Standard **Splices for 16-Mm Motion Picture Films for Projection**	**PH22.24** **(Z22.24)** Revision of Z22.24 – 1941 and Z22.25 – 1941

P. 1 of 2 pp.

Scope. Splices made in accordance with this standard are primarily for use with films intended for actual projection, such as release prints and reversal films. It is not intended that this standard be prejudicial to the use of diagonal type splicers, nor to the use of narrower splices for professional purposes. For negatives and other laboratory films, narrower splices, sometimes with one edge on the frameline, frequently are used.



	Inches		Millimeters	
A	0.100	+ 0.000 − 0.005	2.54	+ 0.00 − 0.13
B	0.548	+ 0.001 − 0.001	13.920	+ 0.025 − 0.025
C	0.324	+ 0.000 − 0.003	8.23	+ 0.00 − 0.08
D	0.324	+ 0.000 − 0.003	8.23	+ 0.00 − 0.08

NOT APPROVED

Proposed American Standard Splices for 16-Mm Motion Picture Films for Projection	PH22.24 (Z22.24) Revision of Z22.24 – 1941 and Z22.25 – 1941

Note 1. In the plan view, the splice is arranged with the perforations at the bottom in order to show them as they appear on most splicers. The splice may be made with the films turned through an angle of 180 degrees, or any other angle, but of course the emulsion surface should always be up. It is customary to scrape the top (emulsion) surface of the left-hand film and to cement this scraped area to the bottom (base) surface of the right-hand film.

Note 2. Dimension A is given a negative but no positive tolerance because narrower splices are less conspicuous on the screen and are less likely to affect the normal curvature of the film as it follows the bends in its path through cine-machinery.

Note 3. Dimension B controls the longitudinal registration of the two films being spliced. It is measured to the perforations that are most commonly used for registration on splicing blocks, and to the nearer edges of these perforations because they are edges that are generally used for the registration. This dimension is made the same as in Z22.77, Splices for 8-Mm Motion Picture Film, because many splicers are designed to accept either 16- or 8-mm film.

The nominal value of the B dimension was made 0.548 inch instead of the usual 0.550 (for unshrunk film) because the films being spliced are always shrunk to some extent. The 0.548 figure corresponds to a shrinkage of 0.36 percent, while the 0.549 and 0.547 values, permitted by the tolerances, correspond to 0.18 percent and 0.55 percent, respectively. Thus, the tolerances include the range of shrinkage ordinarily encountered when film is being spliced.

Note 4. Dimensions C and D were chosen to give a straight 0.100-inch splice that is symmetrical about the included perforation (and, therefore, the frameline) when the film is shrunk 0.36 percent. See Note 3 above.

Note 5. The width of the film at the splice shall not exceed 0.630 inch. If the film has been widened during scraping, the extra width shall be removed.

Note 6. The overlapping perforations of the two films shall not be offset laterally more than 0.002 inch.

Note 7. At the splice, the edges of the two spliced films shall not be offset laterally more than 0.002 inch, unless a difference in the lateral shrinkages of the two strips makes it impossible to maintain that tolerance. Shoulders formed by such misalignment shall be beveled after the cement has dried.

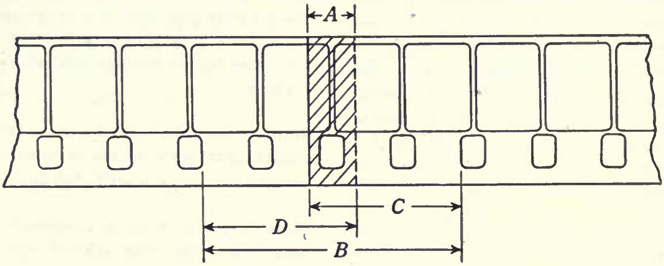
Note 8. In the plan view, the angle between the respective edges of the spliced films shall be 180 degrees, plus or minus 40 minutes. Thus, the spliced film shall be aligned to the extent that when one portion of the film is placed against a straight edge, the other portion will not deviate more than 0.006 inch (approximately the thickness of the film) in 6 inches.

Note 9. In order to prevent the appearance of a white line on the screen, the scraped area shall be 0.001 to 0.003 inch narrower than the area covered by the overlapping film. The presence of this narrow uncemented area will not shorten the life of the splice.

NOT APPROVED

Proposed American Standard Splices for 8-Mm Motion Picture Films	PH22.77 (Z22.77)

P. 1 to 2 pp.



	Inches		Millimeters	
A	0.100	+ 0.000 − 0.005	2.54	+ 0.00 − 0.13
B	0.548	+ 0.001 − 0.001	13.920	+ 0.025 − 0.025
C	0.324	+ 0.000 − 0.003	8.23	+ 0.00 − 0.08
D	0.324	+ 0.000 − 0.003	8.23	+ 0.00 − 0.08

Note 1. In the plan view, the splice is arranged with the perforations at the bottom in order to show them as they appear on most splicers. The splice may be made with the film turned through an angle of 180 degrees or any other angle, but, of course, the emulsion surfaces should always be up. It is customary to scrape the top (emulsion) surface of the left-hand film, and to cement this scraped area to the bottom (base) surface of the right-hand film.

Note 2. Dimension A is given a negative, but no positive, tolerance because narrower splices are less conspicuous on the screen and are less likely to affect the normal curvature of the film as it follows the bends in its path through cine-machinery.

NOT APPROVED

Proposed American Standard Splices for 8-Mm Motion Picture Films	**PH22.77** **(Z22.77)**

Note 3. Dimension B controls the longitudinal registration of the two films being spliced. It is measured to the perforations that are most commonly used for registration on splicing blocks, and to the nearer edges of these perforations because they are the edges that are generally used for the registration. This dimension was made the same as in Z22.24, Splices for 16-Mm Motion Picture Film, because many splicers are designed to accept either 8-mm or 16-mm film.

The nominal value of the B dimension was made 0.548 inch instead of the usual 0.550 (for unshrunk film) because the films being spliced are always shrunk to some extent. The 0.548 figure corresponds to a shrinkage of 0.36 percent, while the 0.549 and 0.547 values, permitted by the tolerances, correspond to 0.18 percent and 0.55 percent, respectively. Thus the tolerances include the range of shrinkage ordinarily encountered when film is being spliced.

Note 4. Dimensions C and D were chosen to give a 0.100-inch splice that is symmetrical about the included perforation (and therefore the frameline) when the film is shrunk 0.36 per cent. See Note 3.

Note 5. The width of the film at the splice shall not exceed 0.317 inch. If the film has been widened during scraping, the extra width shall be removed.

Note 6. The overlapping perforations of the two films shall not be offset laterally more than 0.002 inch.

Note 7. At the splice, the edges of the two spliced films shall not be offset laterally more than 0.002 inch unless a difference in the lateral shrinkages of the two strips makes it impossible to maintain that tolerance. Shoulders formed by misalignment shall be removed after the cement has dried.

Note 8. In the plan view, the angle between the respective edges of the spliced films shall be 180 degrees, plus or minus 40 minutes. Thus, the spliced film shall be aligned to the extent that when one portion of the film is placed against a straight edge, the other portion will not deviate more than 0.006 inch (approximately the thickness of the film) in six inches.

Note 9. In order to prevent the appearance of a white line on the screen, the scraped area shall be 0.001 to 0.003 inch narrower than the area covered by the overlapping film. The presence of this narrow uncemented area will not shorten the life of the splice.

NOT APPROVED

69th Semiannual Convention

After the Advance Notice of the Convention, listing ten technical sessions, went out to Society members on March 9, two sessions were added to make the Tentative Program which has also been mailed. The Tentative Program contained 56 papers and 7 committee reports. Additional copies of the Tentative Program are available from Society headquarters.

Adjustments, indicated as likely at Journal *press time, have been taken into account to show below the transfer of the* Screen-Viewing Factors *and the* Film Projection Symposiums *to Wednesday, concurrent with Wednesday's* High-Speed Photography Sessions, *and to show that Thursday afternoon will probably be used to take up some of the papers shown in the heavy sessions in the Tentative Program.*

APRIL 30—MAY 4

Monday afternoon	Film and Processing
Monday evening	Motion Picture Techniques
Tuesday morning	Television Recording and Reproduction
Tuesday afternoon	Television Session — and Tour of the Bell Telephone Murray Hill Laboratories
Tuesday evening	Television and Motion Picture Production
Wednesday morning	High-Speed Photography
" "	Screen-Viewing Factors Symposium
Wednesday afternoon	High-Speed Photography
" "	Film Projection Symposium
Thursday morning	High-Speed Photography
Thursday afternoon	See Final Program
Friday morning	Magnetic Recording
Friday afternoon	Sound Recording

Each session will open with a motion picture short. A luncheon will open the Convention on Monday noon, and a banquet and dance will be held Wednesday evening. Complimentary tickets to selected Broadway motion picture theaters will be issued to registered members and guests.

Any reader who did not receive the Advance Notice can get a copy from Society headquarters or he can write for reservations (mentioning the SMPTE) direct to: Front Office Manager, Hotel Statler, 7th Ave., 32d and 33d Sts., New York 1.

Also, readers of subscription copies of the Journal need only send a postal to Society headquarters to get a copy of the Tentative Program.

SPADEWORK

Bill Kunzmann, Convention Vice-President, notes that the Papers Committee, listed in the Journal last month, has turned in a fine job. He urges that all who have been asked to help with work assigned to the following chairmen dig in with a will. With their help, all Convention machinery will function smoothly, thanks to these chairmen:

Hotel and Transportation — H. D. Bradbury
Local Arrangements — E. M. Stifle
Luncheon and Banquet — W. B. Lodge
Membership and Subscriptions — L. E. Jones
Motion Pictures — Emerson Yorke

Public Address — H. B. Braun
Publicity — Harold Desfor with Leonard Bidwell and Harry Sherman
Projection, 35-mm — H. E. Heidegger, with officers and members of New York Projectionists Local 306
Projection, 16-mm — T. P. Dewhirst
Registration and Information — E. R. Geib with P. D. Reis, G. H. Gordon and E. A. Hungerford
Television — C. L. Townsend
Ladies' Registration — Mrs. E. M. Stifle, Hostess, with Mrs. E. I. Sponable, Mrs. Herbert Barnett and Mrs. O. F. Neu

Engineering Activities

STANDARDS COMMITTEE MEETING

At its annual meeting held in the last week of January, 1951, the Standards Committee, under the Chairmanship of Frank Carlson, had a very full and fruitful session. The first order of business was a review of the status of all Proposed Standards currently before the Committee, as outlined below:

Approved by Standards Committee and PH22

Cutting Dimensions for 32-Mm on 35-Mm Motion Picture Negative Raw Stock, PH22.73
Zero Point for Focusing Scales on 16-Mm and 8-Mm Motion Picture Cameras, PH22.74
Mounting Threads and Flange Focal Distances for Lenses for 16-Mm and 8-Mm Motion Picture Cameras, PH22.76

Approved by Standards Committee for Submittal to PH22

Sound Transmission of Theater Projection Screens, PH22.82

Approved by Standards Committee for Preliminary Publication in JOURNAL

A and B Windings of 16-Mm Raw Stock Film, PH22.75; published January, 1951
Edge Numbering of 16-Mm Motion Picture Film, PH22.83; published January, 1951
Splices for 16-Mm Films for Projection, PH22.24; published in this JOURNAL
16-Mm Motion Picture Projection Reels, PH22.11; published February, 1951
Dimensions for Projection Lenses, Medium Prefocus Ring Double-Contact Base-Up Type, PH22.84; published February, 1951
Dimensions for Projection Lamps, Medium Prefocus Base-Down Type, PH22.85; published, February, 1951
Splices for 8-Mm Motion Picture Film, PH22.77; approved subsequent to meeting and published in this JOURNAL.

Edge Guiding of 16-Mm Films. The question of edge guiding was then explored in view of an apparent inconsistency in Society policy. In this regard recent Standards, PH22.7-1950, and PH22.8-1950, do not specify a single guided edge, stating that either edge may be used and giving the arguments for each; however, other Standards, PH22.15, PH22.16 and PH22.41, do specify the guided edge. The first two deal entirely with emulsion position and hence the Committee voted to revise these standards, deleting specification of guided edge. However, PH22.41, Sound Records and Scanning Area of 16-Mm Sound Motion Picture Prints, presents several problems:

1. The present tolerances may be dependent on the specification of the guided edge.

2. Advent of 32-mm film as source of 16-mm release prints and consequent slitting problems may require such specification. It was, therefore, agreed that the Engineering Vice-President would refer this to the Sound Committee (to be reviewed by the 16-Mm and 8-Mm Committee) for further study with the directive to revise if this can be done without degrading the present standard.

Glossary. The desirability of compiling

a glossary of technical terms peculiar to the motion picture industry was readily agreed upon. The discussion centered rather on practical methods of achieving this, inasmuch as attempts had been made in the past without appreciable success. It was finally agreed that each committee chairman would be asked to draw up a list of terms he considered vital for inclusion in such a glossary. This could be readily achieved and would provide a basis for further work. It might then be possible, after some discussion, to get immediate agreement on a definition for 75–90% of the terms. A glossary would then exist and, although incomplete, be at least better than nothing at all and a good starting point for further work.

International Standards. Fred Bowditch, Engineering Vice-President, gave a brief history of the International Standards Organization (ISO), noting that the International Standards Association dissolved at the onset of the second World War and that the ISO was formed as an adjunct to the UN. The American Standards Association (ASA) is the United States representative in the ISO and as such holds the Secretariat of Technical Committee 36 (TC36) for Motion Pictures. This means that sectional committee PH22 of ASA should rightfully be handling ISO questions, but in effect, as sponsor of PH22, the final responsibility belongs to SMPTE. A meeting of TC36 had been proposed for this coming summer in Geneva, but the consensus was that in the absence of a specific agenda of recognized importance, there was no real justification for such a meeting now. As Secretariat, ASA had distributed 40 American Standards in 1948 and proposed they be made International Standards. Comments on these have been received from several countries and require additional correspondence on our part. In view of projected ISO meetings in this country during 1952, it might be wise to begin now the preparation of specific agenda.

The ensuing discussion brought out several vital points:

1. Some of the standards submitted have since been revised.
2. The advent of low-shrink film may soon require revision of other standards.
3. Additional standards now exist which may also warrant international standardization. It was therefore agreed that all members of the Standards Committee would inform the Chairmen of those standards which they feel might be important for an International Standards Program and include along with the standard a brief review of the history and present status of each standard.

Very often, material is received from other nations with requests for comments. In such a case, it was agreed that the proper channels for such material should be from the various foreign standards institutes to ASA (PH22) then to the SMPTE Engineering Vice-President and finally to the appropriate engineering committee.

Research Projects. The Engineering Vice-President stated that he had been requested by the Board of Governors, in line with a recommendation by Clyde Keith, to prepare a list of research problems which might be used by graduate students in universities as theses projects. Such graduate research activity can well produce information of value to industry and is thus worth encouraging. He therefore emphasized his earlier written request that each engineering committee consider the preparation of a list of projects in its field, together with brief background material explaining each project.

NEW STANDARDS SOON

Three proposed American Standards are now on their last lap in the course of becoming Approved Standards. Having been approved by the Engineering Committee, the Standards Committee, ASA Sectional Committee PH22 and the Society Board of Governors, they are now awaiting final approval by the ASA Photographic Standards (Correlating) Committee and then the ASA Standards Council. They are:

1. PH22.73, Cutting and Perforating Dimensions for 32-Mm on 35-Mm Raw Stock
2. PH22.74, Zero Point for Focusing Scales for 16-Mm and 8-Mm Motion Picture Camera
3. PH22.76, Mounting Threads and Flange Focal Distances for Lenses for 16-Mm and 8-Mm Motion Picture Cameras

BOOK REVIEW

Acoustical Designing in Architecture

By Vern O. Knudsen and Cyril M. Harris. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. 404 pp. + 45 pp. appendix + 7 pp. index. 180 illus. + 8 tables. 5½ × 8¾ in. Price $7.50.

This is the most readable, useful and practical book on architectural acoustics which we have encountered. Naturally, most of the information can be found in more complete and complicated form in the Acoustical Society Journals, earlier books and other periodical literature. Such a collection, we believe, would be far too extensive and technical for the average architect and engineer (other than the acoustical engineer) to maintain or use to his advantage.

Professor Knudsen's earlier book, *Architectural Acoustics*, embracing much of his original research, furnishes fit foundation for this new and excellent collaboration. Comparison of the two in such matters as sound absorptive materials shows that many of the materials mentioned in the first book have disappeared from the market, while new ones (they generally have coined names) have been developed by a fast-moving industry even since the publication of the present book. Changes such as this can be expected in materials, methods and sound systems, but certainly, the well-presented basic information will remain useful.

The authors have designed this book primarily for architects and students of architecture, and there is no doubt that if an architect will make use of this book intelligently, he will avoid most of the glaring errors which crop up in public buildings. We suggest that Chapters 9 through 14 be read before consigning the book to a shelf. This procedure will probably arouse enough interest to make the reader do the first eight chapters, at least lightly. Chapters 1 through 8 deal largely with the physics of sound and with the nature of speech and hearing. Chapters 9 through 14 are concerned with basic design, the selection of a proper site, arrangement of rooms, control of noise both air-borne and structurally transmitted, and use of sound amplification systems. These parts together offer a fairly simple and lucid explanation of the nature and behavior of sound in its relation to architecture. Specific problems in rooms for special uses are treated in the remainder of the book. Reference may be made to these sections as the need requires.

There is a chapter on each of the following: auditoriums; school buildings; commercial and public buildings; homes, apartments and hotels; church buildings; broadcasting, television and sound-recording studios.

While this book purports to be a nonmathematical treatise, it frequently steps out of character with the sudden appearance of mathematical terms not commonly met with in architecture. These constitute the common language of the acoustical engineer or physicist but probably convey little information to the architect. However, many of the expressions given are interpreted by graphs which, if studied, will supply a fairly close answer.

Undoubtedly, complicated problems will arise where the architect may need the services of a specialist in this field, but his task will be considerably lightened and his resulting design better if he has a basic understanding of the acoustic principles underlying the form and structure being considered.

Aside from the use of this book by the architect and reader of general interest, it is recommended as a good additional reference work for engineers in the sound field. The careful listing of design procedure, the extensive collation of sound-absorbing coefficients of different materials and data on sound transmission of various constructions make the book very much worth while.—James Y. Dunbar, William J. Scully Acoustics Corp., 101 Park Ave., New York 17.

SMPTE Officers and Committees: New rosters are scheduled to be published in the April Journal.

Virgil B. Sease

After 33 years with E. I. du Pont de Nemours & Company, Dr. Sease retired from his activities at Du Pont's Redpath Laboratory, Parlin, N.J., at the end of 1950. He has been a member of this Society since 1926. He became a Fellow in 1934, the year in which the grade of Fellow was established.

Dr. Sease joined the Du Pont Company in 1917 as a research chemist at the Experimental Station near Wilmington, Del. From late in 1917 until 1920 he was engaged in similar activity at the Delta Laboratory, Arlington, N.J., where he worked on the acetylation of cellulose. In 1920 he went to the Redpath Laboratory, Parlin, N.J., where investigations on the manufacture of photographic film were in progress. In 1925, he became director of research for the Du Pont-Pathe Manufacturing Corp., at Parlin. When this organization became Du Pont's Photo Products Dept., he moved to Wilmington in the same capacity. He became technical consultant to the department in 1942 and technical adviser in 1946. He was named director of the development section in 1947.

Dr. Sease's research on photographic emulsions included studies on precipitation conditions, the role of iodide and the nature of gelatins. He was particularly interested in grain size and in this connection worked on the formulation of developers to control graininess. He wrote a number of technical articles on photographic developments and was responsible for the development of a number of patents in the photographic field.

He was born near Leesville, S.C., in 1888. He received his B.A. degree from Newberry College in 1908, was principal of a high school in South Carolina from 1908 until going to Newberry College as an instructor in 1911. He was a fellow at Johns Hopkins from 1916 to 1917 and he received his Ph.D. from Johns Hopkins in 1917. He and Mrs. Sease now live at 1010 Berkeley Rd., Wilmington 67, Del.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 Membership Directory.

Honorary **(H)** Fellow **(F)** Active **(M)** Associate **(A)** Student **(S)**

Aragones, Daniel, Partner, Managing Director, Laboratorio Cinefoto. **Mail:** Ave. Gral. Franco 426, Barcelona. **(A)**

Bennett, Norman, American University. **Mail:** 10707 St. Margarets Way, Kensington, Md. **(S)**

Bischof, Wallace F., 3524 E. Anderson Ave., Albuquerque, N. M. **(A)**

Bodnar, John, Head, International Cutting Dept., Twentieth Century-Fox Film Corp. **Mail:** 1210 Daniels Ave., Los Angeles 35, Calif. **(M)**

Bradish, Albert S., Vice-President in Charge of Production, Atlas Film Corp. **Mail:** 1526 N. Harlem Ave., River Forest, Ill. **(M)**

Bunnell, Ray F., Head, Electrical Dept., Warner Brothers Pictures, Inc. **Mail:**

900 E. Angeleno Ave., Burbank, Calif. (M)

Clayton, Vincent E., Chief Engineer, Radio Service Corporation of Utah. **Mail:** 1525 Browning Ave., Salt Lake City, Utah. **(M)**

Coan, Alexander D., Television Advertising, Philbin, Brandon & Sargent, Inc. **Mail:** 277 Park Ave., New York 17, N.Y. **(A)**

Dance, Darrell A., Chief, Technical Services Branch, Motion Picture Division, U.S. Dept. of State. **Mail:** 15 Arcadia Rd., Apt. 21A, Hackensack, N.J. **(M)**

Davis, Wesley J., Boston University. **Mail:** 125 Homestead St., Boston 21, Mass. **(S)**

de Gorter, Benjamin, Research Librarian, Technicolor Motion Picture Corp. Research Dept., 6311 Romaine St., Hollywood 38, Calif. **(A)**

Faris, Herbert C., General Manager, Tele Sales, Inc. 118 St. Clair Ave., N.E., Cleveland, Ohio. **(A)**

Fitzstephens, John J., Associate Instructor, New Inst. for Film and Television. **Mail:** 315 W. 14 St., New York 14, N.Y. **(A)**

Glubin, Samuel B., New Inst. for Film and Television. **Mail:** 231 Snediker Ave., Brooklyn 7, N.Y. **(S)**

Gomez, Miguel A., New Inst. of Film and Television. **Mail:** 23 A Ulmer Dr., Brooklyn, N.Y. **(S)**

Gordon, Robert N., Manufacturing Engineer. **Mail:** 6009 W. Pico Blvd., Los Angeles 35, Calif. **(A)**

Greenberg, Raymond, New Inst. for Film and Television. **Mail:** 149 Avenue C., New York 9, N.Y. **(S)**

Jantzen, Charles A., Photographic Analysis Co. **Mail:** 582 E. Seventh St., Brooklyn, N.Y. **(M)**

Johnston, Frank B., Sr., Chief Photographer, Philadelphia Inquirer. **Mail:** 1417 Dorset Lane, Philadelphia 31, Pa. **(A)**

MacDonald, Joseph W., New Inst. for Film and Television. **Mail:** 2414 Sullivant Ave., Columbus 4, Ohio. **(S)**

Mahoney, William J., Chief Audio Engineer and Owner, Cinecorders. **Mail:** 1730 Kleemeier St., Cincinnati 5, Ohio. **(A)**

Maloney, T. J., Producer-Director, KEYL-TV, Transit Tower, San Antonio, Tex. **(M)**

McLaughlin, Charles D., Projectionist, Southland Drive-In Theatres. **Mail:** 5655½ Huntington Dr., Los Angeles 32, Calif. **(A)**

Miceli, Ernest, Film Editor and Experimental Cinematographer, WOR-TV. **Mail:** 1745 W. Ninth St., Brooklyn 23, N.Y. **(A)**

Miller, Eugene S., Development Engineer, Eastman Kodak Co. **Mail:** 123 Heberton Rd., Rochester 9, N.Y. **(M)**

Niehus, Murray H., Engineer, Cliffords Theatre Circuit. **Mail:** 313A King William St., Adelaide, South Australia **(A)**

Norbury, Alfred S., Engineering Aide, Corps of Army Engineers. **Mail:** 3526 Harrison St., Kansas City 3, Mo. **(M)**

Nordbye, R. B., Motion Picture Photographer and Director, Great Lakes Prod., Inc. **Mail:** 208 North Hale, Wheaton, Ill. **(A)**

Peltz, Leo G., Hollywood Sound Inst., **Mail:** 1023 N. Edgemont, Los Angeles 27, Calif. **(S)**

Searle, Milton H., Quality Control Engineer, Eastman Kodak Co., Inc. **Mail:** 216-10 47 Ave., Bayside, N.Y. **(A)**

Stagnaro, John A., Chief Station Engineer, KECA-TV, American Broadcasting Co. **Mail:** 1105 N. Louise St., Glendale 7, Calif. **(M)**

Stoddard, William C., Boston University School of Public Relations. **Mail:** Cochituate Road, Wayland, Mass. **(S)**

Tucker, Morris H., Technician, Columbia Broadcasting System. **Mail:** 1530 Archer Rd., Bronx 62, N.Y. **(A)**

Wirth, Charles H., Project Engineer, Rangertone, Inc. **Mail:** 78 N. Spring Garden Ave., Nutley, N.J. **(A)**

Zampari, Carlo, Studio Manager and Associate, Studios Vera Cruz, "São Bernardo do Campo," São Paulo, Brazil. **(A)**

CHANGES IN GRADE

Allen, Eugene S., Jr., Cameraman and Editor, Video Films. **Mail:** 870 Newport Ave., Detroit 15, Mich. **(S)** to **(A)**

Brauer, Howard H., Chief Electronics Engineer, Bell & Howell Co. **Mail:** 1020 Lawrence Ave., Chicago 40, Ill. **(A)** to **(M)**

Hufford, Robert G., Physicist, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif. **(A)** to **(M)**

Jones, Lt. Harold, Jr., Photography Director, U.S. Signal Corps. **Mail:** Apt. 9A, 2026 Magill Dr., Fort Monmouth, N.J. **(A)** to **(M)**

Mann, R. G., Chief Engineer, Pathé News, 625 Madison Ave., New York 22, N.Y. **(A)** to **(M)**

Rockar, Lt. William F., Signal Corps, 301st Signal Photo Co., Camp Gordon, Ga. **(A)** to **(M)**

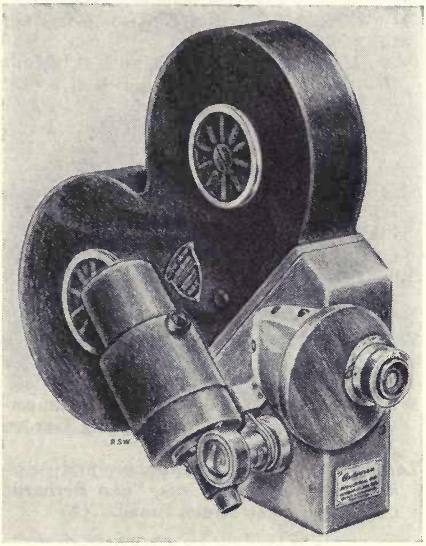
Svancara, V. J., Chief Sound Engineer (Motion Pictures), Wright-Patterson Air Force Base. **Mail:** 1228 Epworth Ave., Dayton 10, Ohio. **(A)** to **(M)**

Tamer, James S., Photographer, Sandia Corp. **Mail:** 3216 A. St., Sandia Base, Albuquerque, N.M. **(A)** to **(M)**

Zimmermann, August H., Engineer, DeLuxe Laboratories, Inc. **Mail:** 1090 Trafalgar St., West Englewood, N.J. **(A)** to **(M)**

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.



A 35-mm recording camera to fill the needs of industrial and research analysts has been designed by A. P. Neyhart, Chairman of the SMPTE's Subcommittee on Industrial and Research Photography, and H. G. Cunningham, camera designer, Hollywood. The Automax, as the new instrument has been named, is being tooled for production in the form shown above by the Guild Laboratories, 6264 Sunset Blvd., Hollywood 28, Calif., with which Neyhart is associated.

Neyhart is the designer of the camera for surgical photography which has been described in the JOURNAL (p. 747, June 1950).

The Automax can be operated, locally or by remote control, at interval rates from one exposure per hour to five exposures per sec and at pre-set cine rates of from 10 to 48 exposures per sec. Film exposure is the same for both interval and cine operation. An external intervalometer is required for automatic sequence operation. A 400-ft Mitchell magazine is standard in the present design but other capacities may be used. The standard design is for an acceleration range of 10 *g* vertical and 5 *g* horizontal, but a special combination is available for greater acceleration loads. A film-driven switch actuates an electric footage counter and also gives remote indication of camera operation. Several types of motors are available for field or mobile use. Power requirements range from 10 w, d-c, to 115 w, a-c, depending on application. Frame registration is accurate to 0.003 in., adequate for motion analysis and motion picture projection. An intermittent movement pin is used to transport and register film.

The camera is 6 × 5 × 2¼ in., with motors extending from 2 to 3 in. on one side. The weight, with aircraft motor, loaded 400-ft magazine and lens, is 12 lb. It is constructed to withstand temperatures ranging from −40° to 160°F.

With a new double-function, mercury arc-lamp power supply, manufactured by the Huggins Laboratories, 778 Hamilton Ave., Menlo Park, Calif., either direct-current or single-flash operation of AH-6 or BH-6 mercury-vapor arc lamps may be obtained from 115-v, 60-cps power. Direct-current operation provides steady light, while pulsed operation gives a brilliance about 200 times greater, with a duration of approximately 10 μsec. Either mode of operation can be selected from a single switch. With d-c setting, the power supply delivers 1 kw, 1.2 amp at 800 v. Open-circuit voltage of 1700 v is supplied for starting the lamp. Standard d-c ripple is about 5%, but lower values can be supplied in special units. With flash operation, the 10 μsec pulse at a power of approximately 2.5 watt-sec is provided by a power capacitor discharging through the lamp by means of a thyratron-controlled spark gap. Maximum repetition rate is 6 pulses per min.

The unit is mounted in a standard relay rack cabinet, and its over-all dimensions are 22 × 31 × 15 in. The manufacturers suggest its application to high-speed, Schlieren, shadowgraph and interferometer photography.

Observer Reaction to Non-Simultaneous Presentation of Pictures and Associated Sound

By Harold N. Christopher

The results of experiments to determine observer reaction to non-simultaneous presentation of pictures and associated sound are reported. Curves are presented for two groups of observers: (1) a conditioned or technical group, and (2) a group more nearly representative of motion picture or television audiences. The data given may be used to predict observer reaction to the lack of simultaneity between picture action and the resulting sound over a range of 0 to 300 milliseconds.

Due to the difference in velocity of light and sound in air, we, as observers, perceive action and then hear the sounds resulting from the action. This has resulted in a natural conditioning which causes the observer unconsciously to restore the action and sound to proper perspective. If, however, the delay in the sound path exceeds certain limits the observer not only becomes conscious of the delay but is likely to voice vigorous objections. Organizations dealing with the recording, reproduction or transmission of pictures and associated sound have recognized this and have found it necessary to maintain a reasonable degree of simultaneity between picture actions and accompanying sounds. It is the intent of this paper to give the results of tests to determine when the lack of simultaneity between the picture and the sound of a televised subject or sound motion picture becomes noticeable and objectionable, thus permitting a quantitative evaluation of the phenomenon.

The method employed was to record observer reaction to a series of presentations of actions and sounds in which the difference between the time of arrival of the visual and aural stimuli was carefully controlled. In order to facilitate the taking of data an arbitrarily determined comment scale was employed and is indicated below.

No.	Comment
1.	Not perceptible
2.	Just perceptible
3.	Definitely perceptible
4.	Definitely perceptible but not objectionable
5.	Somewhat objectionable
6.	Definitely objectionable
7.	Unusable

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by Harold N. Christopher, Bell Telephone Laboratories, Murray Hill, N.J.

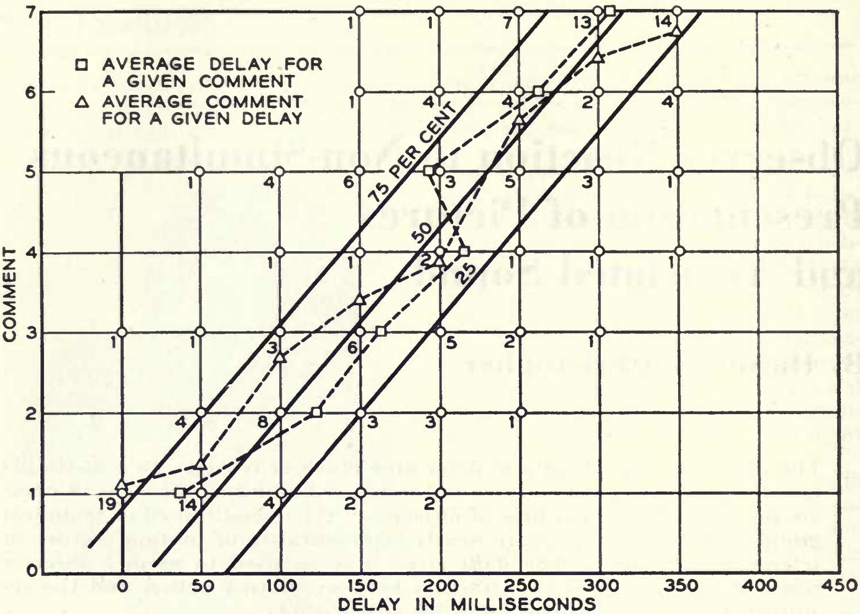


Fig. 1. Mechanical-percussion tests, sound delayed; 20 observers (nontechnical).

Distributions showing the percentage of all observations for an indicated comment number or less, for a given sound delay, (or advance) for talking and striking type actions and the resulting sounds are presented.

Summary of Results and Conclusions

The results of these tests indicate that the ability of an observer to detect the lack of simultaneity between action and the resulting sound is a function of the type of action and whether the sound is delayed or advanced with respect to the action. When the sound follows the action (normal order), delays in excess of about 100 milliseconds are likely to cause adverse comment. When the normal order is reversed and the sound precedes the action, 35 milliseconds advance is about the maximum unlikely to be objectionable. The above conclusions are based on observer reaction to the more easily correlated striking motions and percussion-type sounds. For scenes of people in conversation and moving about, the correlation between picture action and sound becomes more difficult for the observer and the above limits can probably be doubled.

Description of Test and Data

The first test devised and used in this study employed a complete television chain and a tape recorder with a movable reproducing pole-piece. This array of equipment permitted the televising of a subject talking or striking an object and the delaying of the reproduction of the sound by known amounts of time by means of the tape recorder. As the test proceeded, numerous questions arose concerning the adequacy of the quality of the pictures and the sound channel. Both were improved considerably but appeared to have little effect on the results. Direct-viewing tests were then resorted to, eliminating first the television equipment and finally the tape-recording equipment. This was

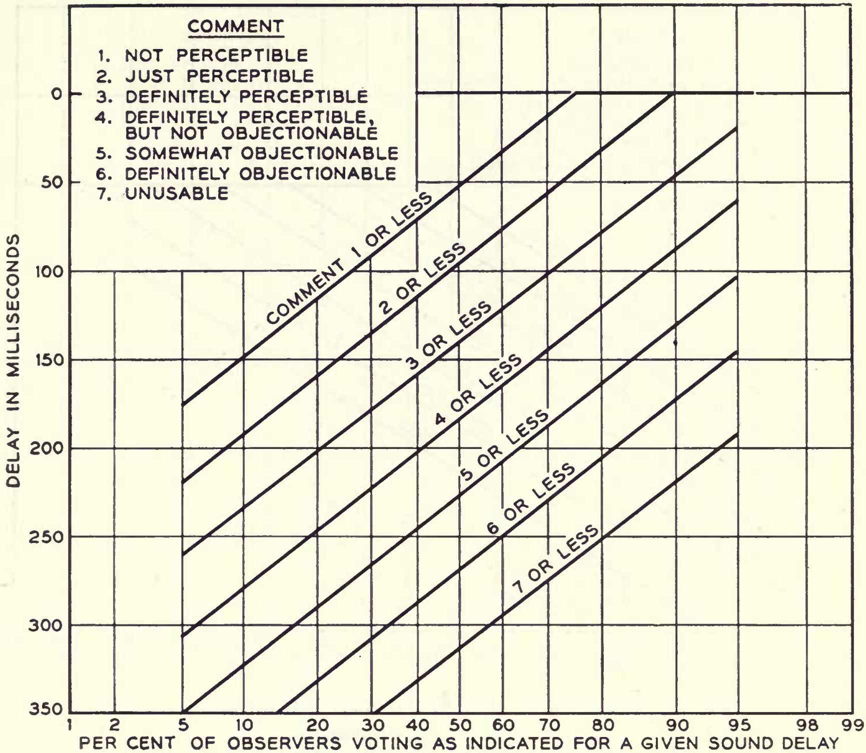


Fig. 2. Mechanical-percussion tests, sound delayed; 20 observers (nontechnical).

made possible by a simple mechanical device consisting of two cam-actuated felt hammers, one of which struck a dead microphone a sharp blow and returned rapidly to its striking position in full view of the observer. The second hammer, not visible to the observer, struck a live microphone causing a sharp popping sound in the sound reproducing system.* By indexing the second cam with respect to the first it was possible to produce at will a sound that was delayed or advanced with respect to the visible striking of the hammer. Only tests herein termed "mechanical percussion" employed this device and were made by determining observer reaction to a presentation of intermixed delays and advances. Tests other than mechanical percussion permitted an irregular presentation of delays only. The instruction to the observers for all tests was to focus their attention on the picture action and vote their reaction to the lack of simultaneous presentation in terms of the numbered comments, a list of which was before them during the test. No time limit was imposed. A given condition was presented repeatedly, and changed only after the observer had commented.

Two groups of observers were em-

* The loudspeaker was located about 3 ft in front of the observer, slightly to his right but almost in line with the action, at about eye level. The striking hammer was approximately 8 ft in front of the observer.

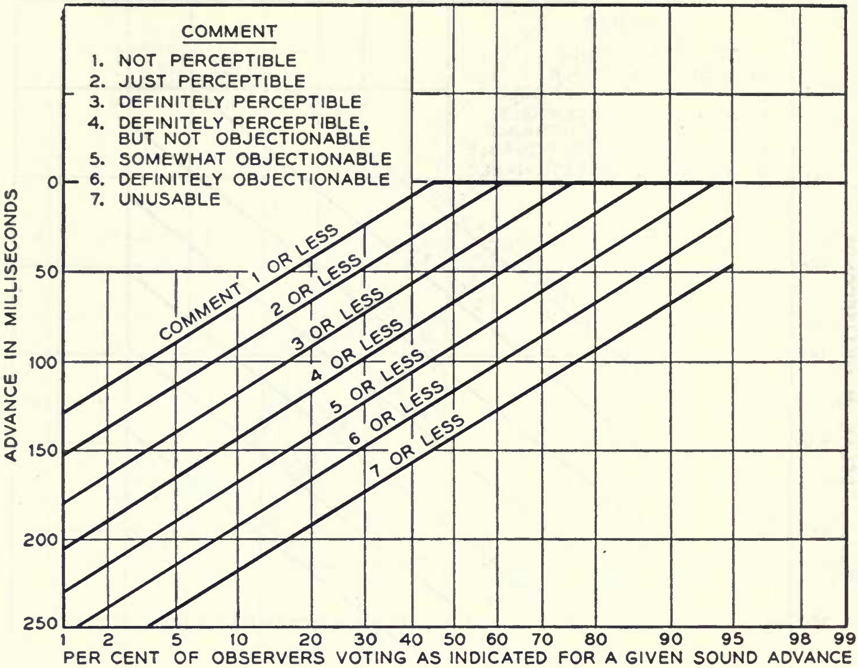


Fig. 3. Mechanical-percussion tests, sound advanced; 10 observers (all engineers).

ployed, the first consisted of a conditioned group, indicated as, "10 observers, all engineers." In each test, however, the observers were not always the same 10 people. They were, in general, engineers familiar with problems involving pictures and sound.

The second group totaling 20 people, consisted of 4 engineers and 16 other observers, most of whom were draftsmen and included 5 women. This group although more nearly representative of a picture audience was comprised of people probably above average in technical background and understanding.

The observer comments for the mechanical percussion tests are listed in Table I. An examination of these data indicates that both observer groups comment more severely when the sound occurs before the action and it also appears that the 10-observer group is somewhat more critical (they comment more severely sooner) than the 20-observer group. The information or intelligence that appears desirable to extract from these data if possible is: (1) how severely would these groups react to a particular delay or advance in milliseconds; and (2) what delay would cause a given percentage of the observers to make the comment 4 or less. This would require two forms of processing, one in terms of average comment for a given delay and the second in terms of average delay for a given comment.

Figure 1 plots the "20-observer, mechanical-percussion test, sound delayed" data in the form of the matrix, in which the numbers at each data point correspond to the total vote for a given comment at that delay as indicated in Table I. The 50% points of the two

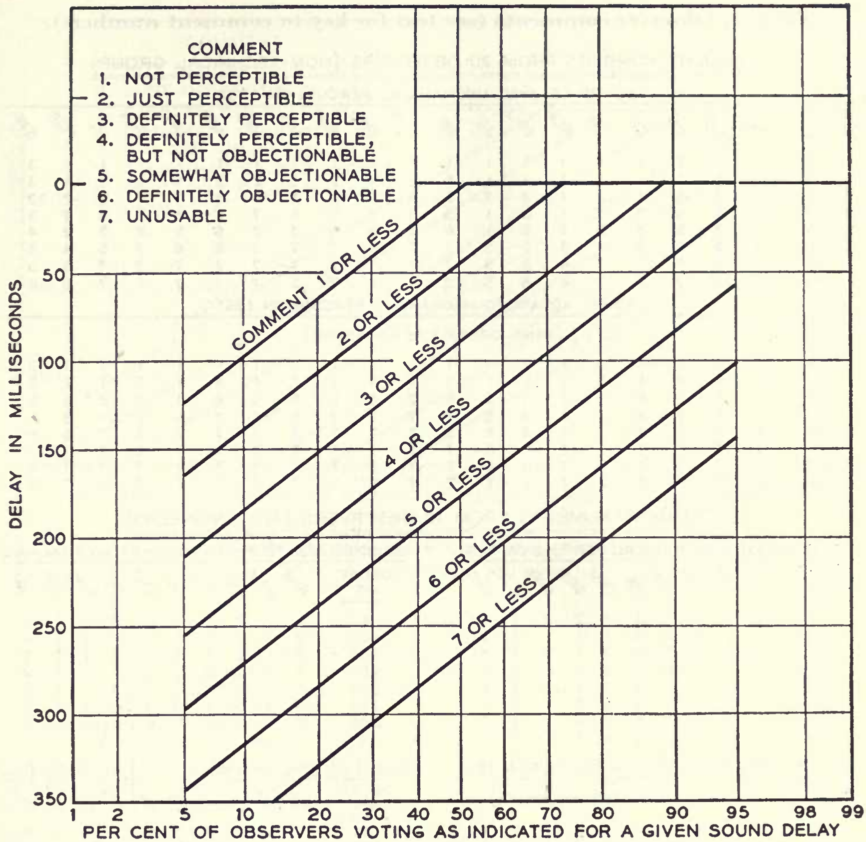


Fig. 4. Mechanical-percussion tests, sound delayed; 10 observers (all engineers).

methods of processing mentioned in the above paragraphs are indicated by the light dashed lines on the matrix. Through these lines the heavy straight line captioned 50% curve has been drawn.

In a similar manner, although not shown in detail, the lines captioned 25% and 75% may be located.

That the calculated 50% values deviate in an irregular way from the straight-line 50% curve is evident and typical of all data presented here. It is felt, however, that the straight-line 50% curve as indicated is a practical representation of the observer's evaluation of the delay phenomena in terms of the comment scale, for either method of processing. It is also plain that straight line curves labeled 95% or 5% if shown on Figure 1 would fall in meager data areas and, therefore, would perhaps be less representative than the 50%, 25% or 75% curves.

Figure 2, a cross plot of the straight-line data shown on Fig. 1 results in a family of curves indicating how the 20-observer group reacted to delaying the sound with respect to the action for the mechanical-percussion test.

Let us assume, for example, that we wish to predict how this group of people

Table I. Observer comments (see text for key to comment numbers).

COMMENT NUMBERS FROM 20 OBSERVERS (NON-TECHNICAL GROUP)

SOUND DELAYED MECHANICAL PERCUSSION TEST

DELAY MS	EK	JM	RB	CE	LP	RLF	FRM	JC	RE	CHH	DWQ	JLW	HTS	HAS	ADF	MFW	EHH	ML	HGR	STP
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3
50	1	1	1	1	1	1	1	1	5	2	1	2	1	2	2	1	1	1	1	3
100	1	2	5	1	2	2	2	1	5	3	2	2	3	5	5	1	4	2	2	3
150	2	5	5	3	5	1	3	1	5	3	3	5	5	7	6	3	2	4	2	3
200	1	3	5	3	6	2	2	1	6	3	5	4	3	7	6	5	6	3	2	4
250	3	6	5	5	7	3	2	5	7	7	5	7	7	7	6	6	7	5	4	6
300	6	7	6	7	7	4	3	5	7	7	7	7	7	7	7	7	7	7	5	5
350	6	7	7	7	7	4	6	5	7	7	7	7	7	7	7	7	7	7	6	6

SOUND ADVANCED MECHANICAL PERCUSSION TEST

(SAME OBSERVERS AS ABOVE)

ADVANCE MS	EK	JM	RB	CE	LP	RLF	FRM	JC	RE	CHH	DWQ	JLW	HTS	HAS	ADF	MFW	EHH	ML	HGR	STP
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
50	4	2	4	1	3	1	1	1	1	1	4	1	1	1	4	1	1	1	2	2
100	6	4	7	5	3	1	1	5	6	2	6	6	6	5	6	1	7	2	2	5
150	7	3	7	6	7	4	3	5	7	7	7	7	7	7	7	5	7	7	3	5
200	7	7	7	7	7	5	6	6	7	7	7	7	7	7	7	7	7	7	6	6
250	7	7	7	7	7	7	6	6	7	7	7	7	7	7	7	7	7	7	7	7
300	7	7	7	7	7	7	6	6	7	7	7	7	7	7	7	7	7	7	7	7
350	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

COMMENT NUMBERS FROM 10 OBSERVERS (ALL ENGINEERS)

SOUND DELAYED MECHANICAL PERCUSSION TEST

DELAY MS	ADF	MB	COM	CRM	RA	CFM	GRS	MKA	WTW	VWD
0	2	1	1	1	1	1	2	2	1	1
50	3	5	3	2	1	1	1	1	3	1
100	2	5	4	5	2	2	1	5	7	5
150	3	7	7	6	2	4	4	4	7	4
200	6	7	7	5	4	5	4	7	7	6
250	7	7	7	7	3	6	6	7	7	7
300	7	7	7	7	6	7	6	7	7	7
350	7	7	7	7	5	6	6	7	7	7

SOUND ADVANCED MECHANICAL PERCUSSION TEST

(SAME OBSERVERS AS ABOVE)

ADVANCE MS	ADF	MB	COM	CRM	RA	CFM	GRS	MKA	WTW	VWD
0	1	1	1	1	1	1	1	1	1	1
50	1	5	1	6	1	5	4	1	2	2
100	6	6	7	7	5	7	6	7	7	7
150	7	7	7	7	6	7	6	7	7	6
200	7	7	7	7	6	7	6	7	7	7
250	7	7	7	7	7	7	6	7	7	7
300	7	7	7	7	7	7	6	7	7	7
350	7	7	7	7	7	7	6	7	7	7

SOUND DELAYED TELEVISED TEST-H.G.FISHER TALKING

DELAY MS	RHB	MFM	JH	MKA	GN	DMC	DC	RWE	ADF	HGF
40	1	1	2	1	1	2	2	1	1	1
100	2	1	1	1	1	2	1	1	1	1
125	2	1	2	1	1	3	1	1	1	1
150	3	1	1	3	2	2	1	1	1	2
200	5	1	2	3	2	5	3	1	2	3
250	5	3	5	4	3	5	4	4	2	6
300	7	6	5	6	5	6	6	4	5	6

SOUND DELAYED WINDOW TEST-H.G.FISHER TALKING

DELAY MS	RHB	MEM	VWD	JRH	BG	MWB	WTW	MVS	ADF	RWE
40	1	1	1	2	2	1	1	4	1	1
100	1	1	2	2	1	1	1	4	1	1
125	1	1	4	3	2	1	1	4	1	1
150	1	2	3	3	3	1	3	5	1	1
200	2	5	3	4	1	3	2	4	1	1
250	5	6	5	6	5	7	5	6	2	2
300	6	7	4	7	5	7	6	5	2	2

would react to a delay of 100 milliseconds in the sound track of a motion picture involving motions that result in percussion-type sounds. From Fig. 2 we note that 87.5% would make the comment 4 or less (12.5% would vote 4 or more), that 96% would vote comment 5 or less, and 4% would comment more severely than comment 5. In other words, with this family of curves, if we know the delay we can determine or predict how many observers would object to the non-simultaneous presentation.

Figures 3, 4 and 5 are to be interpreted as described above for Fig. 2 for the observer group and test conditions indicated in the figure captions.

Data from two other tests are given in Table I. One test employed a complete television chain and tape recorder to produce the various delays, and in the other the speaker was observed through a window in a sound-proofed panel, the sound being delayed by means of the tape recorder.

These data, when processed as previously described, resulted in distribu-

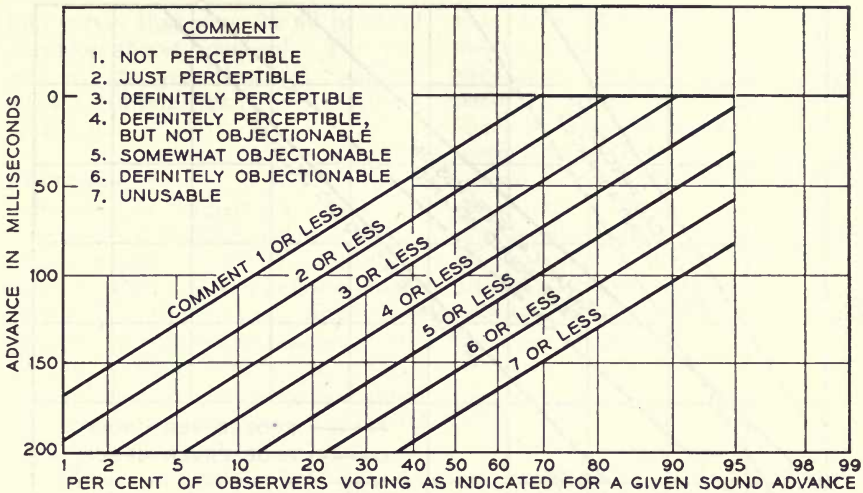


Fig. 5. Mechanical-percussion tests, sound advanced; 20 observers (nontechnical).

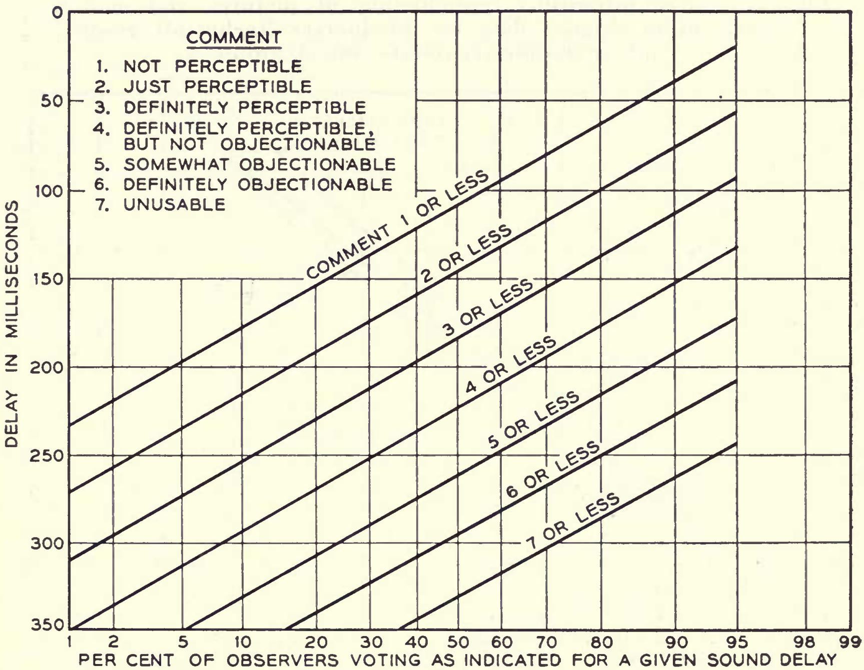


Fig. 6. Average of talking tests; 10 observers (all engineers). Effect of delay in terms of comment scale.

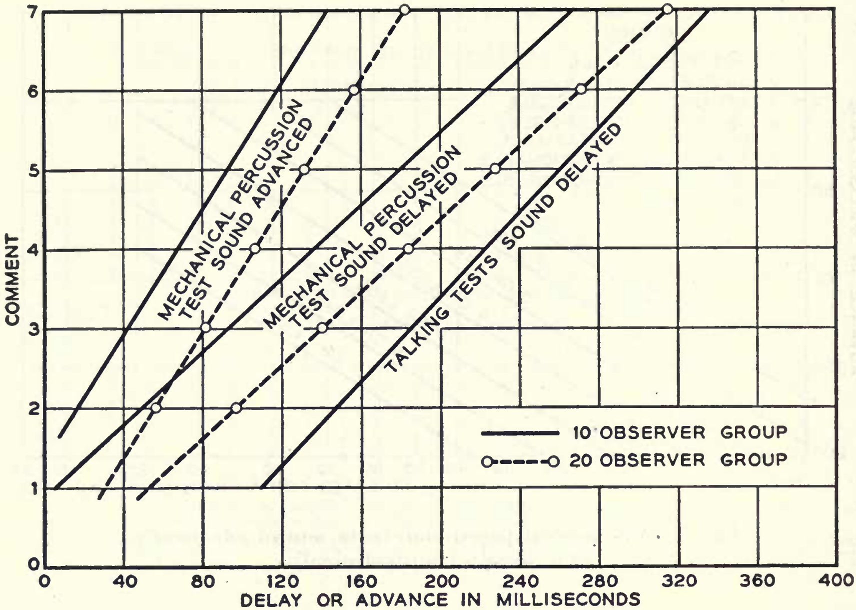


Fig. 7. Non-simultaneous reproduction of pictures and sound; comparison of average data for 10-observer (technical) group and for 20-observer (nontechnical) group.

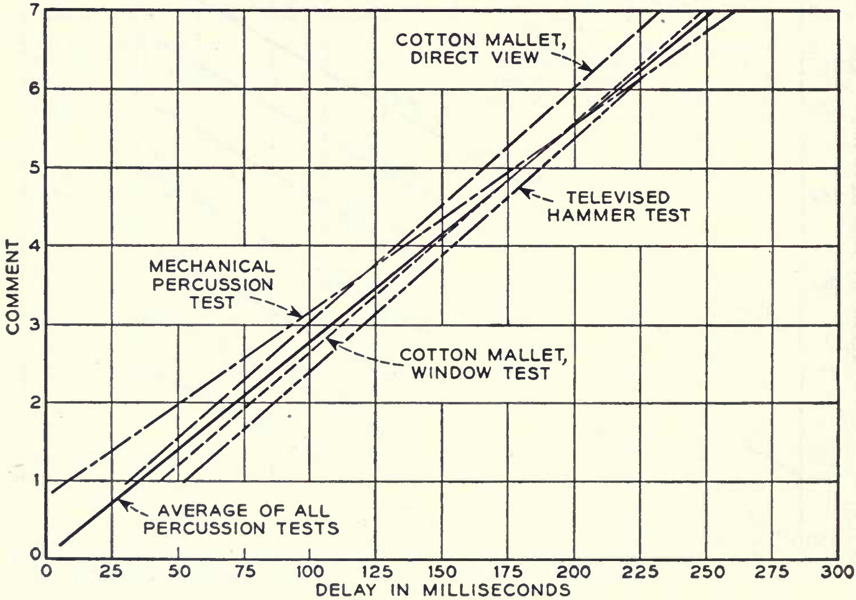


Fig. 8. Comparison of percussion data; 10 observers (all engineers).

tion curves that were for all practical purposes almost identical. The two sets of data were therefore combined and the resulting distributions are shown on Fig. 6.

Discussion

In order to compare the reaction of the two groups for the various test conditions a plot of the 50% values as found on Figs. 2, 3, 4, 5 and 6 is shown on Fig. 7. Here we have milliseconds delay or advance versus comments, and we can compare directly the average curves of the two groups for the various test conditions. From Fig. 7 it is seen that although the 10-observer group detects delays or advances before the 20-observer group, the curves for the two groups parallel each other. A constant difference of approximately one comment is indicated for the delay condition and 1.5 comments for the advance condition. This points out a rather nominal difference between the average technical and the average nontechnical observer. If this difference could be attributed to education, it is possible that repeat data on the 20-observer nontechnical group might more nearly approach the evaluation of the technical group. Another factor not discussed but evident in the tabulations on Table I is that of audio-visual coordination. The importance of this factor and the education factor cannot be determined from the data presented here.

Comparing the talking test with the mechanical-percussion test for the 10-observer group it will be noted that the average observer finds it more difficult to detect the delay for the talking test and therefore appears more tolerant of delays that involve correlation of sounds with lip motions. The slope of the talking test curve indicates a somewhat different evaluation of the delay phenomenon; the difference however appears too small to be significant.

As mentioned briefly in the description, tests other than direct-viewing mechanical-percussion and talking tests were made. Figure 8 shows, for comparison purposes, four different percussion-type tests employing the 10-observer group. These curves show a remarkable similarity when one considers the following facts: (1) the greatly different presentation as indicated by the curve captions; and (2) that although 10 observers are indicated for each test, the observers were not always the same 10 people.

Conclusions

Observer reaction to non-simultaneous reproduction of pictures and sounds has been rated subjectively by means of an arbitrarily determined scale of comments.

Although a nominal difference is indicated in the evaluation of the phenomenon for technical and nontechnical observers, the subjective reactions of the two groups are almost exactly parallel.

The average observer detects earlier and voices more vigorous objections to advances than delays.

For delays, the objectionable effects of the more easily correlated actions and sounds (percussion type), though detected at considerably shorter delays than those between lip motions and the corresponding sounds, appear to grow at approximately the same rate.

Differences in presentation that involved picture and sound quality have little or no bearing on the evaluation of the more easily detected delays.

The repeated similarity of processed data when displayed or compared in the form of average curves (Fig. 8) suggests that the findings herein presented, though determined from observations of a relatively small number of people, would be changed or modified rather little had a greater number of observers been employed.

The Television Cameraman

By Rudy Bretz

The requirements of the television medium and the unique design of television cameras have developed, in the best of television cameramen, operators of unusual skill. A broad picture of the abilities and backgrounds of present-day television cameramen is presented, and a general comparison is made between the television cameraman and the motion picture camera operator. The creative role of the cameraman and his relationship to the television director are explained in an outline of the stages of camera rehearsal.

Handling the camera is a highly creative job, and there is a tremendous difference between a good and a mediocre cameraman. The ability of a television cameraman depends on certain basic abilities, but is also due in large measure to his attitude toward his job. This in turn seems to hinge primarily on the position of the cameraman within the station organization.

About half the stations have been classifying cameramen as engineers. Not all of these require the cameraman to have a very thorough technical knowledge. At about half of these stations, the cameramen-engineers are assigned to camera operation and nothing more, and they are expected to be experts only in the art of camera handling. The balance of these stations employ no cameramen as such, but apply a policy of rotation of the engineering personnel. An engineer may be assigned to the camera one week, to maintenance of equipment the next and as technical director the third. This is considered good management because it keeps the staff flexible; in case of illnesses or vacations it is possible to replace people easily, and more can be accomplished with a smaller staff. However, all engineers must then be well-trained technical men with a thorough knowledge of circuits and electronics. In most cases, such men do not particularly care for camera handling. Operating the camera calls for none of the special knowledge and skill which the technical man has acquired through his years of engineering study. At the same time, his background has been weak in the understanding of composition, picture showmanship and the visual arts. In many stations the engineers speak of the camera assignment as the "salt mine," endure it for as long as they must and make very little effort to contribute anything creative to the production at

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A contribution submitted January 10, 1950, by Rudy Bretz, Television Consultant and Producer. This is part of a forthcoming book and is published by permission of McGraw-Hill Book Co., Inc. Critical discussion of this material is particularly invited, either in the form of Letters to the Editor or by communication directly to the author at Croton-on-Hudson, N.Y.

hand. In such a setup the producer has a much more difficult job doing a good show.

The other half of television cameramen are classified in the production departments. They are responsible to the program director rather than to the chief engineer. Some stations even rotate personnel between cameras and other production jobs. A man may direct one show, take the camera for the following production, and then put in a stint as audio-console operator or projectionist before the next show that he produces comes around. This is, of course, only possible in small towns where there are no iron-clad union jurisdictions. Such rotation means efficient station operation, and at the same time assures that the camera work will be as creative as possible. It also helps to eliminate social strata within the production organization.

The job of cameraman is only one of a group known as operating jobs. Such duties as dolly-pushing, mike-boom operating, audio-console operating, the jobs of technical director, projectionist, record spinner, etc., are not strictly *technical* jobs. In none of these positions does the operator have to understand more than the mechanics of operation of his equipment. He is not called upon to repair or redesign, but only to operate, and skill of operation rather than engineering is required. A few television stations do classify all these jobs under the program department. An understanding of showmanship is of greater value than a technical background in an operating job, and when production people are placed in these positions creative contribution is more likely to result.

This is not to say, of course, that no engineers have any concept of showmanship. There are many engineers in television who, through particular backgrounds or extensive control-room experience in television or radio, have developed an understanding of the elements of showmanship that would actually qualify them as directors. The best of the "technical directors" fit this description.

Aptitudes of the Successful Cameraman

Whatever the cameraman's classification with the organization may be, he will become really good only if he has two essential aptitudes. The first is a sense of composition and the second is a well-developed manual coordination.

The sense of composition comes only from long familiarity with a picture medium. A man who has been a still or motion picture photographer, or perhaps has worked on a picture magazine, has been thinking in terms of pictures and developing this sense. "Reading up" on composition doesn't help. It is not possible for the television cameraman, or director either, for that matter, to apply rules for composition while he is making pictures. He must be able to look at a picture, see what is wrong with its composition, and, by a conditioned reaction, as the psychologist would put it, unerringly make a quick adjustment to improve it.

Manual dexterity and coordination come only to those who are endowed with the necessary aptitude. Just as it is impossible to teach some people to fly an airplane, so it is impossible to teach some people the smoothness and dexterity necessary to operate the television camera. A man who lacks the feeling for composition, but has coordination, may learn the former in time; if he lacks the aptitude for physical coordination, he will never be a good television cameraman, no matter how finely developed his pictorial sense may be.

Television and Motion Picture Cameramen

Perhaps the unique nature of the television cameraman can best be explained if he is compared with the near-

est thing which existed before the advent of the television medium—the motion picture cameraman. The comparison is not an easy one to make and possibly an accurate parallel can be drawn to only one phase of the film cameraman's work. For one thing, the television cameraman has no responsibility for lighting or exposure, or for picture quality except in regard to composition and smoothness of camera movement. He compares most closely to the operating cameraman in Hollywood who, as an assistant to the director of photography, is concerned only with handling the camera.

At first comparison the television cameraman is seen to have a lot more to do than his motion picture counterpart. The job of handling a motion picture camera is only a job of framing the picture. The camera operator controls the camera with the panning handle, pans the camera left and right, or tilts it up and down to keep a good composition. If the camera dollies in or out, or the subject moves toward or away from the camera, the focus must be adjusted on the lens barrel, but the cameraman has an assistant to help him in this operation. The assistant rides on the front of the camera dolly watching chalk marks on the floor. As the dolly wheel passes the 10-ft mark, he sets the lens to 10 ft; as it passes 8 ft, he has moved the focusing scale to 8, and so forth. If he cannot see the chalk marks on the floor, a second assistant walks alongside and whispers the distances in his ear. It is clear that this method of following focus can only be used when adequate rehearsal of each shot is possible. The television camera had to be designed so the cameraman himself, without preplanning, can adjust focus to whatever motion is taking place within the scene.

The television cameraman will often control his own camera movement as well. Many of the camera dollies used in television stations today may be operated by one man and, in general, a good cameraman can usually work better alone than with an assistant.

In the television camera, then, more aspects of the camera's operation are under one man's control. This gives him more work to do in one sense, but relieves him of a great burden at the same time—the burden of coordinating the actions of two or more operators. When one man is operating, he is subject to a certain possibility of human error. When two men are operating the same camera, however, the factor of human error is not merely doubled, it is multiplied by four. Each man's errors reflect upon the other. When as many as three operators must cooperate in the operating of a single camera (the counter-balanced-crane type of camera dolly requires three men), the factor of error may be increased by nine. Equipment such as this can be used to best advantage only when plenty of rehearsal time is available.

The exception to this is the cameraman-dollyman team which has worked together so long that each man knows the other's reflexes and the two can operate with a single accord even when covering spontaneous action.

The television cameraman develops more rapidly in his craft and reaches a high level of skill in much less time than it takes his motion picture counterpart. This is due to two factors: the actual amount of camera handling he does, and the fact that he can see his results as he works.

In the usual motion picture studio, the largest part of shooting time is taken up in adjusting lights, rehearsing actors and in a thousand details of production. If an average day's shooting amounts to, say, five minutes of finished film, it can be assumed that the camera was in actual operation on takes and retakes, or on rehearsals before the takes, perhaps a maximum of twenty or thirty minutes. It was only during this time that the cameraman was practicing his

skill. Like a musician who spends most of his day adjusting his piano, and only thirty minutes playing the instrument, he has acquired only a half hour of practice toward the mastery of his instrument.

The television cameraman, on the other hand, works his eight-hour day in almost constant camera manipulation. The director invariably comes into the studio with more show to produce than he has rehearsal time for, and pushes the camera crew as hard and as fast as he possibly can. Of course, the cameraman is not working at top efficiency all this while—if there are two or three cameras involved in the studio rehearsals, only one bears the entire burden of the production at any one time, while the others reposition for their next shots. There are moments, too, when the director is concerned with problems of acting, staging or audio, during which the cameraman can relax. It is safe to say, however, that a good three hours of his eight-hour day are devoted to actual camera handling. In comparison with the motion picture cameraman, then, he gets six times the experience in the same period of time.

Not only does the television cameraman get more training, but he gets better training because he can see the results of his efforts as he works. The motion picture man is at a great disadvantage in this respect. He must resort to complicated routines of measurement, using light meters and measuring tapes, simply because he cannot see whether the picture is well exposed or whether the subject is in focus. Likewise, the film cameraman who executes a dubious pan shot may think it is entirely acceptable until he sees it on the screen the next day. During that twenty-four hours, however, he has allowed a false impression to crystallize in his mind. He must find out his mistake and unlearn it before he can return and improve his technique. The television cameraman is under no such disadvantage. A poor shot is immediately evident to him; he corrects the error at once, and the lesson has been learned.

With these factors in mind, then, it is easy to understand why the best of television camera work is on such a high level. A good cameraman, after a year or two on the television camera, has learned his equipment so thoroughly that it is practically an extension of his own body. He can seemingly make the camera do anything and go anywhere, and do it smoothly and perfectly the first time. He has developed techniques of handling the cameras and the camera dollies which the manufacturers of the equipment never imagined. It is not correct to say that the best of television camera work is superior or even equal to the best of motion picture shooting—the film medium will probably always show superiority in production techniques. The flexibility of the television camera, however, and the ability of the cameraman to produce complicated shots smoothly and without rehearsal, is something entirely new in camera handling, and in this the good television cameraman is far superior to his motion picture counterpart.

Television camera techniques are beginning to influence motion picture production and will probably have a wide application in the studios where speed and efficiency in production are important. Methods of continuous shooting have been developed where several cameras operate at one time, repositioning between shots much in the manner of television cameras. One method utilizes a small industrial television camera which is coupled to each film camera enabling the director to watch the shots and direct the cameraman from a control position just as in television production. In motion picture production of this type, the film cameraman is operating in the same manner as a television cameraman, al-

though his equipment is somewhat different.

The recent development of the television recording technique, which makes it possible to film a television show off the face of a kinescope tube and distribute it among television stations, just as any film is distributed, may well become a standard method of film production, at least of films for television use. Recent improvements in television recording technique indicate that the time is not distant when television cameras and studio equipment will be installed by film producers, and the motion picture camera operator will have to learn the television cameraman's technique.

Creativeness in Television Camera Work

The television director is responsible for planning the creative use of the camera, although he may lean heavily on the advice of his cameramen or his technical director.

Some stations, notably those operated by NBC, use the "technical director" system, in which the technical director operates as a kind of head cameraman. He will be familiar with the show rehearsals, and will have had a share in the planning of shots and camera angles. During studio rehearsal he is in charge of the operation and placement of cameras, and is usually the only one who gives directions to the cameramen.

Proponents of this system see in it an analogy to the method of Hollywood production, in which each film has two directors, one of whom is the "Director of Photography" and is in charge of all technical aspects of the production, while the other who carries the title of "Director" concerns himself largely with the broader problems of staging and acting. One director, who has directed programs on many stations, has said that working under the NBC system is like having a twin directing the program with you. During rehearsal much time can be saved. When in the course of rehearsal a stopping point is reached, the director can go out on the studio floor, make corrections in the action and come back to the control room to find all the camera changes made and everything ready to go again. Of course, this is predicated on the ability of the technical director. He must have almost as good a background as the director himself. He must be primarily a showman, not an engineer. Where this method is in use, however, the job of technical director is always an engineering job. The technical director must be in charge of the camera and control-room crew, and for this reason must be a superior engineer. Men who can fulfill all these requirements are rare or cannot be found for the salaries that are offered.

The technical-director system breaks down when an inexperienced man is on the job, or when an "ad-lib" show is attempted. The writer has observed a green director, a green technical director and green cameraman attempt to use this method; and the results were miserable. The director would give a camera order, and the technical director would garble it a little in relaying it to the cameraman, since he had no clear idea of what was meant. Then the cameraman would do the wrong thing. "No! I didn't mean that!" the director would tell the technical director. "I meant so-and-so!" This was again relayed to the cameraman. This time the cameraman would make an error. When it was all finally straightened out and everyone knew what it was the director wanted, it would turn out to be something that couldn't be done anyway because of some technical factor which no one had anticipated.

During an ad-lib show, camera and cutting instructions must be given very rapidly and acted upon immediately, or action is lost. Sudden instructions to the cameramen cannot originate in the

director in these cases, since by the time they are relayed through the technical director, the moment has passed. To be sure, the technical director himself may make the sudden decisions; but he is acting then in the capacity of director, which very few technical directors are able to do, or would be allowed to do. A good technical director could assist the director by keeping one step ahead of him. He could so engineer the cameras that the director would have a variety of shots to choose from in calling takes, and one camera at least would always have a good shot, well framed, from the proper angle to show the action, and ready at the right time. However, there is some question as to whether this could not be done just as well or more easily by the director himself. It is a general opinion that for ad-lib shows the technical-director system does not work. Since most television stations must do the ad-lib type of production (and practically all remote pick-ups fall into this category) most stations (90%) have decided against this method.

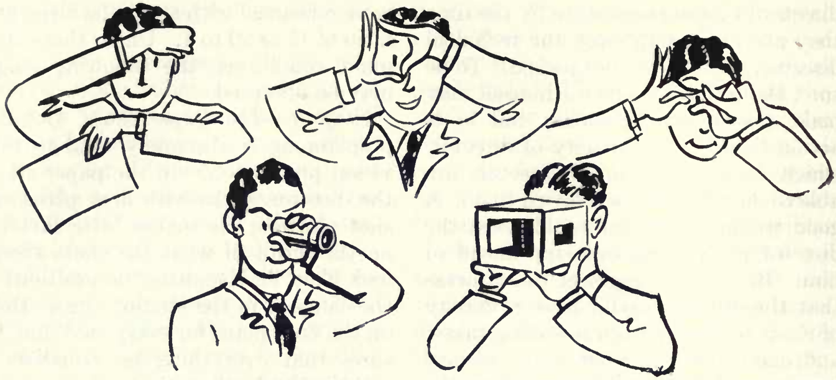
A good compromise is achieved in some stations, and some network studios where both the director and the technical director may talk to the cameramen at any time. This makes quick decisions possible and at the same time provides a two-director team for the rehearsal and production of the show. After operating under this joint system many people have observed that the usual method, whereby the technical director simply operates the switching system under the director's command, wastes the capabilities of this individual who could be assisting the director at the same time.

From script to screen the production may go through many stages, or few, depending on the complexity of the production, and the time allowed for rehearsal. Commercial dramatic programs usually enjoy a rehearsal ratio of 10 hr of rehearsal with cameras to 1 hr of air time. Sometimes important shows have rehearsed with studio facilities at a ratio of 15 or 20 to 1. Under these optimum conditions, the following stages may be observed.

Stage 1—The Paper Stage. Detailed preplanning is absolutely vital to television production. In the paper stage, the director works with floor plans and shot plotters; he makes little sketches on the script of what the shots should look like; he visualizes the positions of the cameras in the studio; draws them on the floor plans for every shot, and insures that everything he visualizes is practical and will work.

Stage 2—Outside Rehearsal. Rehearsals of complicated shows always begin outside the studio in a rehearsal hall or some suitable space. The plan of the studio sets is marked off on the floor; chairs or other furniture are used to simulate sets and props, and the performers get a good idea of the space in which they are to work. Here the director will move about, taking the place of one camera and then the other, as he views each shot from the position of the camera that will take it. Some directors use a portable view-finder with lenses, which will give them the field of view of the television camera lenses. This instrument is available on the market at a rather high figure. Other directors use homemade view-finders, frame viewers or a simple shoe box finder with a cut-out mask. Most directors, however, frame a picture with their own hands. Some use their arms, some their fingers, but the result is the same—an easier visualization of a picture within a 3×4 frame. (See illustration on following page.)

If it is possible economically, the ideal thing is to show the cameramen an entire rehearsal of a show outside the studio before the first use of cameras on the studio floor. Studio rehearsal with facilities is, to a large extent, a period for briefing the cameramen, the floor manager, the stage crew and the control-room personnel on the many aspects



Several methods which directors use to help them plan camera shots.

of the show which the director has previously worked out on paper and with the cast. If the cameramen have seen the show before rehearsal, much of this time can be saved. Further, the cameramen are authorities on the problems of space and traffic on the studio floor and can spot difficulties of which the director may be unaware. And finally, the creative mind of the cameraman, and his own powers of visualization, are a great help to the director in this planning stage.

Stage 3 — Dry-Run. Many directors prefer to use their first hour or so of studio rehearsal for a dry-run, that is, to walk through the show from beginning to end without using the electronic facilities at all, working with the cameramen and crew on the studio floor. Positions of cameras and angles of view are more easily visualized here than in either the paper stage or in the outside rehearsal stage of development.

Stage 4 — Rough Run-Through. A fourth stage is sometimes added here—a straight run-through of the entire show, paying no attention to all the mistakes, rough places and problems that turn up. This can be very valuable for the crew, especially for the stagehands who must make scene changes or work props during the show. Only a complete run-through with cameras can give them a total picture of the show, and without it they will be somewhat confused until the last dress rehearsal puts all the pieces together for them.

Stage 5—Work-Through (Stop-Start). This stage is the stop and start or "work-through" which will take up the major portion of the rehearsal period. The director works through the show, stopping whenever necessary and working out all his problems as he comes to them. It is during this rehearsal that all the fine details of camera work will be set, and the cast and cameras will be coordinated.

Stage 6 — Run-Through. The sixth stage is the final run-through which is done preferably without stopping. Some directors will run through the show as many times as possible before air time, others may rest content with one good dress rehearsal and spend the remaining time working on difficult sequences. More often, there is time for neither, and sometimes a show is worked through so close to air time that there is not sufficient time for a complete run-through at the last. Most of the small stations, when they attempt dramatic shows or other complicated types of programs, cannot allocate sufficient rehearsal time for all these stages. In such cases, all the steps are eliminated except the paper stage, the outside rehearsal and the work-through.

Opinion is divided as to how much responsibility should be vested in the cameraman for finding the right shot at the proper time. In the case of the unrehearsed show where there is no set sequence of shots, the cameraman is usually relied upon to "hunt for shots" when he is off the air. The director may look at a shot the cameraman has found and say: "No, I don't want to use that," or "that's good, give it to me again when I tell you," or he may switch it immediately into the program.

At the opposite end of the scale is the method of operation in which the cameraman makes no move at all, except the very obvious, without instructions from the control room. It is a generally accepted principle that a cameraman should operate like this while his camera is on the air, but most stations give him greater freedom and more responsibility between shots.

In the case of the scripted and rehearsed show, the cameraman will always be supplied with cues from the control room to remind him of his next shot each time he is switched off the program line. In many studios, however, he is expected to take the major responsibility, and will keep a cue sheet on the camera listing each shot as it becomes established in rehearsal. He will often mark the studio floor so he can find the exact camera position that was established in rehearsal for each shot.

Some of the better cameramen are strongly opposed to this method, however; they feel that the important thing is the shot, not the camera position, and since the actors' positions may vary between rehearsal and air, the camera may sometimes be on the right mark and not have the proper shot at all. This same principle is relevant to the calling of lenses. Some directors like to specify the lens that will be used on each shot, and call for that lens during the show. These cameramen feel that much more flexibility should be possible, and that the cameraman need only be reminded of the shot he is to take and then allowed to find it, using his own discretion as to the necessary lens or camera position.

A Simplified Index for Color of Illuminants

By Frank F. Crandell, Karl Freund and Lars Moen

A new improved unit for the trichromatic measurement and description of illuminants is presented. Described are: methods of derivation; relation to Kelvin color temperature scale; application to color film, filters and light sources; and a three-color instrument for measurement of light sources using this new Spectra Index unit.

One year ago, at the Society's Convention, a paper was presented on "The Effects of Color Temperature on Motion Picture Production."[1] It was pointed out at that time that for practically as long as color photography has existed, photographers and cinematographers have been plagued by the problem of color balance between the sensitized material employed and the light source to which it was exposed in making a picture.

Some illuminants, such as flash, are quite constant in color. Incandescent light is variable but can be held within fair tolerances. Some sources are unsuitable for existing color films, though reasonably constant in hue.

Daylight, however, is quite another story. The amounts of red, green and blue in daylight change with the hour, the season, the altitude and latitude, with the state of the sky and the weather, with atmospheric contamination—in a word, with so many variables that no table and no computer could possibly cope with them. As for the human eye, it is a notoriously poor judge of illuminants because of its elastic power of adaptation.

In a confused situation such as this, no one will dispute the need of two specific things: an adequate instrument for the measurement of the spectral energy distribution, or color balance, of any given illuminant, and a convenient unit or index number in which the readings of that instrument can be expressed.

The solution of this problem which has existed until the present is well known to most color photographers. For lack of anything better, a unit was borrowed from the illuminating engineers—Kelvin color temperature. This is the temperature on the Kelvin or absolute temperature scale to which a black body would have to be heated to give off light of the color in question.

The unfortunate shortcoming of "color temperature" is that, while it may be quite accurate in dealing with incandescent light sources (which are virtually "black bodies"), it is wholly inadequate in dealing with daylight and most other artificial illuminants. The

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Presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., (read by Norwood L. Simmons), by Frank F. Crandell, Karl Freund and the late Lars Moen, Photo Research Corp., 127 W. Alameda Ave., Burbank, Calif.

reason is simple. The Kelvin scale is adequate for the ratio of any given *two* colors in the spectrum (say, for example, the middle of the red and the middle of the blue) but for any given third color there is only one possible value at a given ratio of the other two. For example, for any given blue–red ratio, green can have only one value, as expressed in Kelvin color temperature. Since any illuminant other than incandescent lamps is highly likely to have more green or less green than a black body, color temperature fails to describe it.

Since incandescent lamps commonly used for color photography can be rated on the Kelvin scale, the practice has grown up, rather haphazardly, of marking color film as Type A (3400 K), Type B (3200 K), and "Daylight" (Kelvin temperature not specified, though usually assumed to be 5900 or 6100 K).

This has worked reasonably well in practice, under perfectly normal conditions. However, many kinds of "daylight" prove to be something quite other than what the film was balanced for by the manufacturer.

When it comes to describing the properties of filters, Kelvin temperature breaks down completely. If a given correction filter, for example, alters color temperature 100° with incandescent lamps, the same filter at daylight temperatures may have an effect amounting to three or four hundred degrees!

The first step toward clarification of this muddled situation was the development of a photoelectric instrument which would enable the photographer to measure color temperature instead of guessing it—the Spectra Color Temperature Meter. However, this still left the uncertainty as to the green content of a light source, and made it necessary to consult a table for the selection of a color temperature altering filter.

For more than a year, therefore, extensive work has been done on the development of a simple system to describe and interrelate the properties of light sources, color film and color correction filters by the use of an index number, making description of color of the illuminant as simple as setting an exposure meter with an ASA film speed index.

The first step was the development of a new Spectra, no larger than the previous instrument, which would measure both the blue–red ratio and also the green–red ratio, of any given light source. This is called the Spectra Three-Color Meter (see Fig. 1). The next step was to find a system for the calibration of these two scales that would be simpler, more rational and more informative than the Kelvin scale.

A tentative proposal for such a system was put forward in the paper previously cited,[1] in order to sound out industry opinion on the subject. Comments have been received from scientists, from manufacturers, from cameramen and photographers, and from illumination engineers. Many of their suggestions have been extremely helpful and have been adopted; all were heartily in favor of such a rational system; none favored retention of the clumsy Kelvin temperature scale.

The results of all this have been incorporated in a new index which describes the properties of a light source, a color film or a correction filter, known as the SI or Spectra Index.* This index is derived directly from the mathematical

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* This system of indices for light, film and filters is referred to as the Spectra Index (SI) system and where no ambiguity results, Spectra Index (SI) may be used for any one of the individual values. However, where the distinction between light, film and filter is to be denoted, the light index is referred to as Spectra Distribution Index (SDI), the film index as the Spectra Sensitivity Index (SSI) and the filter index as Spectra Transmission Index (STI).

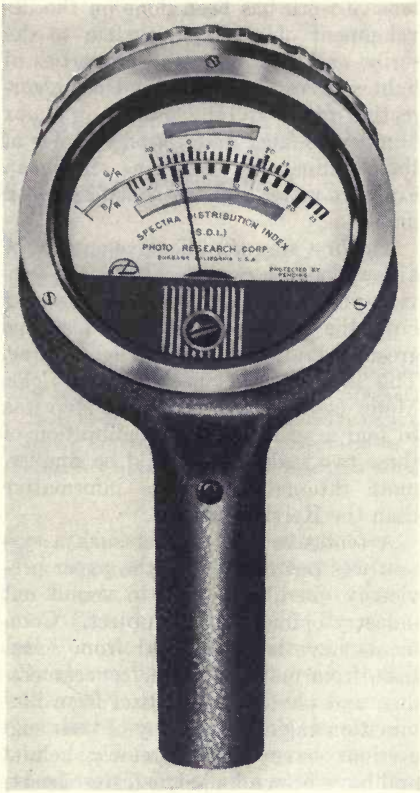

Fig. 1. The new Three Color Spectra Meter.

It reads both the blue–red and green–red balance of the prevailing illumination so that correction can be made for illuminants that fall off the black-body locus, as well as those that are on the locus.

properties of black-body radiation,† and can be duplicated by any manufacturer in any part of the world. It is felt that this step is as important in clarifying a muddled situation as was the original introduction of the Weston film-speed number for use with photoelectric exposure meters.

In the paper presented a year ago, it was proposed that the index be derived from the logarithms of the readings obtained through a special set of standard filters—a method which resulted in a straight-line locus for black-body radiation at all useful Kelvin temperatures, with equal divisions for equal differences of temperature, provided that the latter was expressed in Micro-Reciprocal Degrees (MRD).

However, it has been pointed out that the artifice of the standard filters can be dispensed with, and the index derived directly from the mathematical properties of black-body radiation. If we take Wien's law for black-body radiation:

$$J_\lambda = \frac{C_1\lambda^{-5}}{e^{C_2/\lambda T}}$$

where C_1 and C_2 are the radiation constants;
J_λ is the energy at a given wavelength, λ; and
T is the temperature on the Kelvin or absolute scale;

and take the log of the ratio of the energy at two wavelengths λ_1 and λ_2 then

$$\log_e \frac{J_{\lambda_1}}{J_{\lambda_2}} = A + \frac{B}{T}$$

where $A = 5 \log_e \left(\frac{\lambda_2}{\lambda_1}\right)$

and $B = C_2 \left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)$. The resulting graph of $\log_e \frac{J_{\lambda_1}}{J_{\lambda_2}}$ against $\frac{1}{T}$ (the reciprocal of the Kelvin temperature) is a straight line.

Carrying this line of reasoning a step farther, it is evident that if the log ratios of one pair of spectral lines, plotted against reciprocal Kelvin temperatures, yield a straight-line graph, then the log ratios of two pairs of lines, plotted against each other, will also

† In the derivation of the units in the Spectra Index system, use is made of the complete spectral distribution of a black body at a given Kelvin temperature and not just to its visual appearance or "color temperature."[2]

yield a straight line, the slope of which may be considered the vector of the rate of change of the two sets of ratios.

This is what has been done in setting up the scale of Spectra Index values. Since Wien's law is substantially valid in the region from 2000 to 10,000 K, it may be considered suitable for dealing with all light sources likely ever to be used in color photography. If desired, a very slight departure from linearity in the upper part of the scales will bring the reading into line with exact temperatures according to Planck's law.

However, taking advantage of the useful mathematical properties of the straight-line locus, two important changes have been made in the index since it was first proposed. First, the logs of the blue–red and green–red ratios have been multiplied by arbitrary constants, so chosen that a difference of 10 MRD in a light source will result in a difference of exactly one unit on the blue–red scale and of one-half unit on the green–red scale. (The reason for the use of the one-half unit will appear in the discussion of correction filters, later in this paper.) Second, for further convenience, a constant has been added to both numbers to bring the index of a 3200 K light source to exactly zero on both scales.

The value of these changes is obvious. Since 10 MRD is generally accepted as the just perceptible difference which will create a visible difference in the resulting color reproduction, the tolerance at any point in the scale becomes one-half unit. Since all light sources used in color photography have a color temperature of 3200 K, or higher, only positive values will normally be encountered. This eliminates the possible confusion of negative indices for illuminants below 4000 K, and positive indices for values above, as first proposed.

The formulas for the conversion of color temperatures to the Spectra Distribution Index and vice versa are extremely simple. They are:

$$\mathrm{SDI}_{\mathrm{B-R}} = 31.25 - \frac{100{,}000}{T}$$

$$\mathrm{SDI}_{\mathrm{G-R}} = 15.63 - \frac{50{,}000}{T}$$

$$T = \frac{100{,}000}{31.25 - \mathrm{SDI}_{\mathrm{B-R}}}$$

$$T = \frac{50{,}000}{15.63 - \mathrm{SDI}_{\mathrm{G-R}}}$$

in which

$\mathrm{SDI}_{\mathrm{B-R}}$ = Blue–Red Spectra Index
$\mathrm{SDI}_{\mathrm{G-R}}$ = Green–Red Spectra Index
T = Kelvin temperature

In practice, the values for the two ratios are combined, with the blue–red figure coming first; if the B–R value is 5.5 and the G–R value is 2.8, the complete SDI is 5.5/2.8. It will be noted that for equivalent black-body radiation the G–R index must always be one-half of the B–R index (rounded off to the nearest tenth.) If this is not the case, we immediately know that the illuminant in question is off the black-body locus.

The application of the foregoing to color film and to illuminants is immediately apparent. The SDI of an illuminant tells us all we need to know of its properties for trichromatic photography; the SSI of a color film is simply a statement of the illuminant color which will yield the best balanced reproduction on that particular film or coating. This still leaves the question of correction filters to bring the two into balance. This problem has been met in a way which is believed to deserve somewhat extended treatment, since it represents a more comprehensive and systematic approach to the question than any known previous effort.

Consider first the graph shown in Fig. 2 which is the graph of light sources shown as Fig. 10 in the July, 1950, Journal paper[1] now redrafted to fit the new Spectra Index. The illuminants, from A to M, are listed in Table I. This takes in the color space bounded

Table I

	Illuminant	Color	Simplified Filter Designation*	SI or STI†
A.	Studio broadside	4 steps too yellow		
		2 steps too magenta	4 T	4/2
B.	170 M-R lamp with 5070 (Y-1) glass	3 steps too yellow		
		1 step too magenta	3 T	3/1.5
C.	Noon sunlight	3 steps too yellow		
		1 step too magenta	3 T	3/1.5
D.	Whitelite 6300	1 step too yellow	1 T	1/0.5
		1.5 step too magenta	1 G	1/0
E.	Daylight on horizontal plane; fairly clear	Correct	—	—
F.	Same; clear	Correct	—	—
G.	Sun outside the atmosphere	1 step too blue	1 S	−1/−0.5
H.	Graf AC H-I Arc	1 step too blue	1 S	−1/−0.5
I.	Complete overcast	1 step too blue	1 S	−1/−0.5
J.	Whitelite 7100	1 step too blue	1 S	−1/−0.5
		1 step too magenta	1 G	0/1
K.	Illuminant C	1 step too blue	1 S	−1/−0.5
L.	Sunshine Arc, white flame	9 steps too blue	6 S	−6/−3
		2 steps too magenta	3 S	−3/−1.5
			2 G	0/2
M.	North sky, clear	9 steps too blue	6 S	−6/−3
		6 steps too green	3 S	−3/−1.5
			1 M	0/−1

* See footnote on p. 395. † See footnote on p. 388.

by Spectra indices 8 to 24 in the blue–red and 1 to 13 in the green–red. For purposes of orientation, this embraces roughly the color temperatures from 4000 to 15,000 (somewhat more in the green–red), and thus takes in any possible light source which might be corrected for use with daylight type color film.

This graph may be considered rather similar in its properties to the UCS color triangle. As we move upward on this chart, light becomes more greenish; as we move to the *right*, it becomes more bluish.*

Now, let us set ourselves the hypothetical problem of correcting any illuminant which might be encountered within this color space so that it will give a balanced result on daylight-type color film. If the color of illuminants were a random matter, and we were likely to

* On Judd's Uniform-Chromaticity-Scale (UCS) triangle our two axes would correspond more closely to a line from the right (blue) corner to the middle of the left side (yellow or minus blue) as the B/R axis and the line from the top (green) to the middle of the bottom (minus green or magenta) for the G/R axis. There have been many proposals recommending two axes more or less in the blue–yellow, green-minus–green directions: Adams[3] uniform chromaticity system, Hunter's[4,5] alpha-beta chromaticity system, and Robertson and Milligan's[6] yellowness–greenness system, to name only three. They seem to have in common at least approximately uniform chromaticity scales with neutral gray as their center and an ease in visualizing the hue represented by given coordinates.

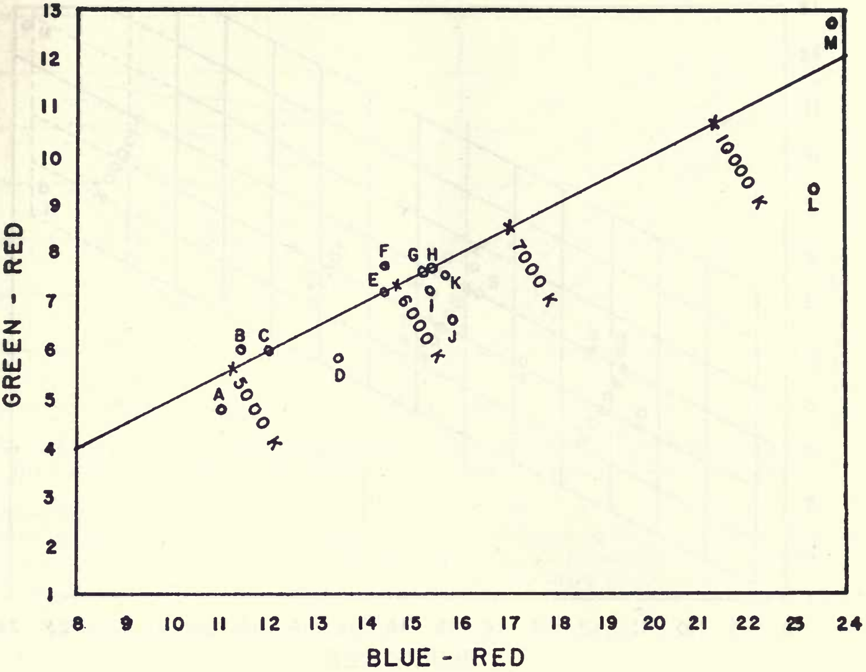

Fig. 2. Thirteen widely assorted illuminants plotted in Spectra Index coordinates.

The diagonal line is the black-body locus. This graph has been redrawn, in terms of the revised Spectra Index values, from Fig. 10 in the Authors' paper in the July, 1950, Journal, p. 85. The illuminants, A to M, are identified in Table I, p. 390.

encounter in practice light sources which fell anywhere within the diagram, then the simplest solution of the problem would be a set of filters which shifted the balance along rectangular coordinates, i.e., a plus- or minus-blue series and a plus- or minus-green series.

However, the color of illuminants is not a random matter. Thirteen real light sources, both natural and artificial, have been plotted in Fig. 2, marked A to M. It will be noted that these light sources tend very strongly to group along the black-body locus. Expressed in another way, the similarities of real illuminants to black-body radiation are greater than the differences. It will be noted that two quadrants of the chart, the upper left and the lower right, which are farthest from the black-body locus, have no illuminants plotted in them at all. For obvious psychological and technical reasons, this is likely to continue to be true. The only illuminants which would fall far from the black-body locus would be highly colored sources, such as the sodium lamp or the old mercury vapor tube, which are not suitable for color photography with any possible degree of correction.

This leads to an important conclusion regarding the problem of correction filters. Since all illuminants tend to be in the neighborhood of the black-body locus, there are obvious advantages in having one set of correction filters so designed that it shifts the hue of an illuminant in the direction parallel to the

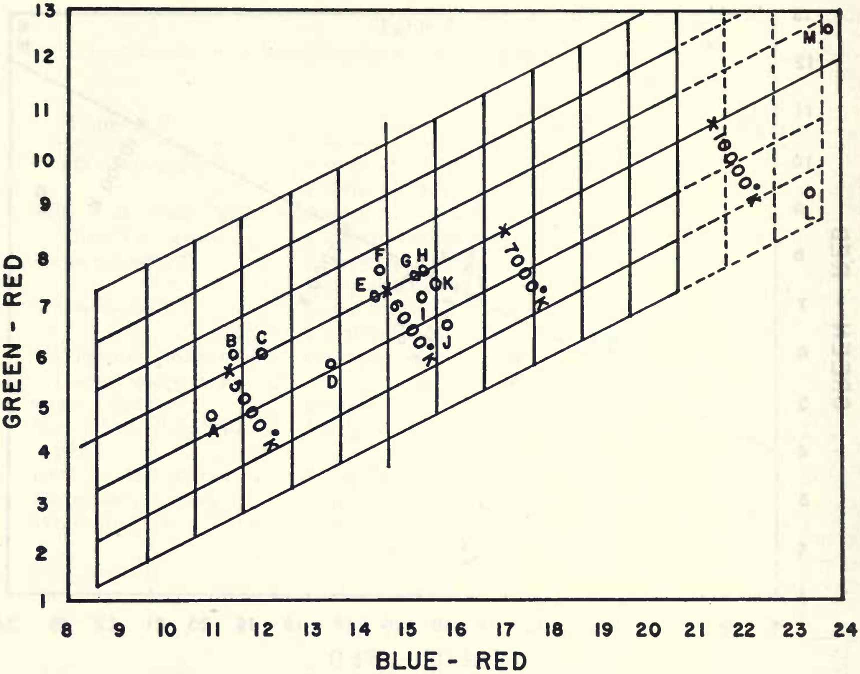

Fig. 3A. The same illuminants as those shown in Fig. 2, with the addition of a grid representing the coordinates of the four series of correction filters, salmon, turquoise, green and magenta.

This grid is not static, but is always shifted so that its O-O point is located at the Spectra Index of the light source being used, and the number of squares that must be traversed to arrive at the SDI of the film (for example, 6000 K, or SDI 14.6/7.3, indicates the filter required). In practice, the entire operation would be carried out, not by means of a graph, but by setting the computer which is illustrated elsewhere.

black-body locus. In a large number of cases, the total required correction can then be made with a single filter.

For this purpose, we require filters with sloping rather than sharp absorptions. Instead of pure yellow (minus-blue) we must use a pinkish yellow which, for each unit of blue which it absorbs will absorb half a unit of green. Instead of a blue, we must use a more greenish hue, having a half-unit of green with each unit of blue. Such a series, of course, is substantially what has been used in the past for the correction of color temperature.

This takes care of the blue–red correction. There remains the question of any additional green–red correction which may be required. Superficially, it might well be assumed that the logical method of accomplishing this would be to use a series of greenish and pinkish filters which would shift illuminant color in a direction perpendicular to the black-body locus. Thus, the filters would be evenly spaced along a series of rectangular coordinates with the entire grid at an oblique angle.

However, a little reflection will show that the logic of this is only apparent,

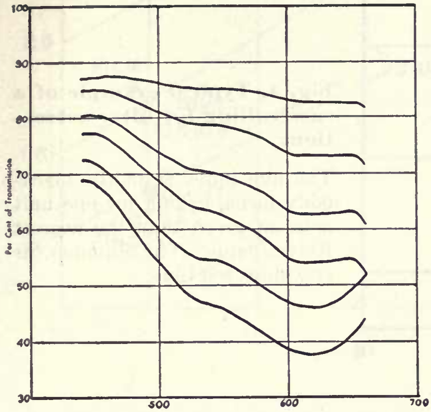

Fig. 3B. Spectral transmission curves for CT-1T through CT-6T filters.

These filters increase the blue–red ratio twice as much as they increase the green–red ratio, so they correct in the direction of increasing black-body temperature.

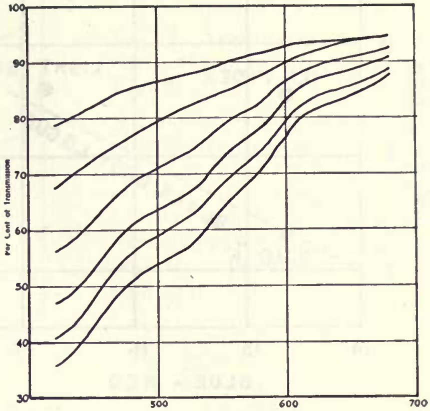

Fig. 3C. Spectral transmission curves for CT-1S through CT-6S filters.

These filters decrease the blue–red ratio twice as much as they decrease the green–red ratio, so they correct in the direction of decreasing black-body temperature.

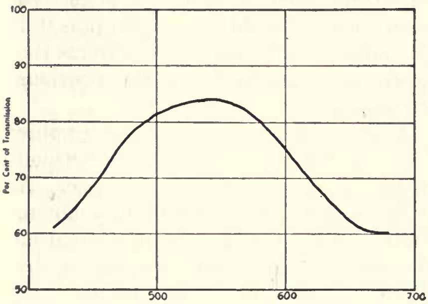

Fig. 3D. Spectral transmission curve for GC-3G filter.

This filter reduces blue and red equally, so increases the green–red ratio only.

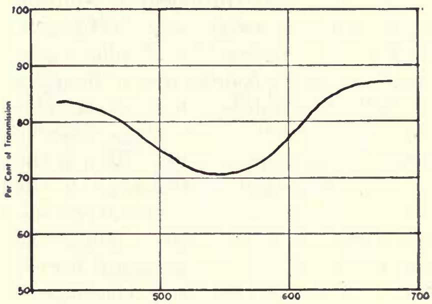

Fig. 3E. Spectral transmission curve for GC-3M filter.

This filter reduces principally green leaving blue–red ratio unchanged but reduces the green–red ratio. Note that GC-3G and GC-3M combine to form a photographic neutral.

and that the drawbacks would outweigh the advantages. Our yellowish and bluish filters affect both the blue–red and the green–red ratios, which is correct and desirable, since it keeps the shift parallel with the black-body locus. However, if we were to use pinkish and greenish filters which shifted the hue at right angles to the locus, then these filters would also affect both ratios. As a result, the choice of the correct filter would become a matter of the greatest complexity. The filter from the salmon–turquoise series which gave the

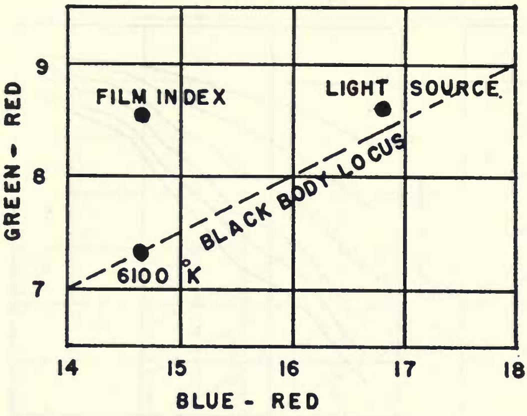

Fig. 4. Typical example of a case calling for filter correction.

The film index is off the black-body locus, calling for one unit more of green than the nearest Kelvin value. The illuminant is two steps too blue.

desired blue–red correction would also shift the green–red ratio. When allowance was made for the latter, and a suitable pink–green filter selected to supply the remaining green–red correction needed, this filter would then upset the blue–red ratio!

The final and truly logical solution which has been arrived at is best shown in Fig. 3A (same as Fig. 2, plus a grid representing the coordinates of the series of correction filters; 6 to raise color temperature, 6 to lower it, 3 to diminish green and 3 to increase it. Sliding the grid back and forth corresponds to the action of the computer.) As will be seen, the blue–red control filters (known as the CT or Color Temperature series) shift the illuminant along coordinates parallel to the black-body locus. The green–red control filters (known as the GC or Green Control series) shift the illuminant along coordinates perpendicular to the graph, which means that they alter the green–red ratio but do not significantly affect the blue–red figure. This releases us from the interdependence of the two filters involved in the previous proposal, and makes the second filter quite independent of the first. (See also Figs. 3B–3E.)

A simple numerical example will indicate how this works out in practice. Let us say that a particular color film has been found to have a Spectra Index of 15/8. The illuminant which we want to use measures not 15/8 but 11/5. This means that we must add 4 units to the blue–red and 3 units to the green–red. To obtain the necessary blue–red correction we apply a +4/2 CT filter, which balances the blue–red and leaves us still in need of 1 unit of green–red correction. For this, we add a plus 0/1 GC filter, which completely corrects the green without disturbing the previous correction.

Another example is shown in graphic form in Fig. 4, a typical case which might be encountered in practice. A region in the vicinity of 6100 K is shown. Dots indicate the best balance point of the film and the meter reading of the illuminant which we wish to use. In this case, we see that the "best balance" point of the film is off the black-body locus, requiring additional green. The illuminant is two steps too blue.

The solution of this problem is shown in Fig. 5. (Addition of a 2-unit salmon filter brings the blue–red ratio to the correct level. This still leaves us 1 unit low in the green–red. The addition of a 1-unit green filter brings film and illuminant into close balance. All of this would be carried out by simply setting the computer.) The application of a −2/−1 filter shifts the illuminant two steps to the left, but also lowers it one square. A second filter, a 0/1, places

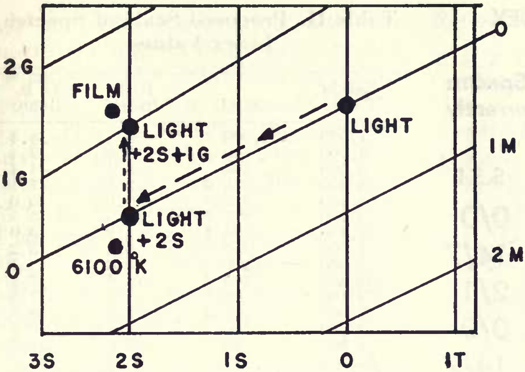

Fig. 5. Application of filter correction to the data of Fig. 4.

A 2-unit salmon filter brings the illumination to the correct blue–red ratio, but the green–red ratio is now 1 unit low. The addition of a 1-unit green filter corrects the index of the light so that it is practically identical with that of the film.

the illuminant very close to the required color balance.*

Actually, none of the arithmetic implied in the foregoing need actually be performed by the user of the meter and filters. A computer has been designed (see Fig. 6) which performs the entire operation. The computer is set for the film index, meter readings are taken, the computer scales are set for the readings obtained, and the required filter or filters appear in the windows on the computer. A card showing values of the Spectra Indices will be published from time to time (see Fig. 7).

At this point, it may be interesting to return to Fig. 3 and summarize the kind and degree of correction necessary for the use of these 13 illuminants with daylight color film. On this chart we assume that we are dealing with a batch of film which is in best balance for an illuminant of 6000 K, or SDI 14.6/7.3. The 13 illuminants would require the filters as listed in Table I to correct them to a film of this balance.

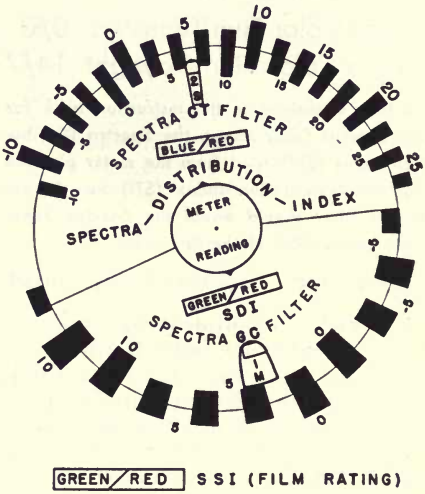

Fig. 6. The computer furnished with the meter.

By means of this meter readings are converted directly into the required filter numbers. Never are more than two filters required to make complete correction.

It cannot be too strongly emphasized that the foregoing is not a guide to the correct use of filters. Color film bal-

* For easy identification and to avoid use of + or − symbols which might be overlooked, the filters are marked as follows: Positive CT filters, B–R ratio followed by "T" for turquoise; Negative CT filters, B–R ratio (sign omitted) followed by "S" for salmon. On the CT filters, G–R ratio has been omitted since it is always $^1/_2$ of the B–R ratio. Positive GC filters are marked with the G–R ratio followed with "G" for Green, and, negative GC filters marked with G–R ratio (sign omitted) followed by "M" for Magenta. Since the B–R ratio is always zero for GC filters it is omitted from the marking.

SPECTRA SENSITIVITY INDEX (SSI)

The following table shows the Spectra Sensitivity Index (SSI) for currently available color films:

EASTMAN FILMS	**S.S.I**
Ektachrome Type B	0/0
Ektachrome Daylight	14/7
Kodachrome Type A	2/1
Kodachrome Type B	0/0
Kodachrome Daylight	14/7
ANSCO FILMS	
Ansco Color Film Tungsten	0/0
Ansco Color Film Daylight	14/7

As fully explained in the instruction book for the Spectra Color Meter, the Spectra Distribution Index (SDI) read from the meter plus the Spectra Transmission Index (STI) for the required filter should equal the Spectra Sensitivity Index (SSI) of the film used.

Copyright, 1950 Photo Research Corp., Burbank.

Fig. 7. Example of Spectra Sensitivity Index Card.

Triple cards like this will be issued from time to time by Photo Research Corp. for meter owners until such time as manufacturers may mark the Index on each package of film.

anced to a different hue would alter all of the values; also the illuminant values are mainly isolated examples, and the same illuminants might yield widely different readings in other cases.

For those interested in the equivalence of Spectra Indices to Kelvin temperatures, without the labor of computing them, Table II has been prepared.

In Table II, values marked with an asterisk correspond to the indices most useful in connection with color photography. Consider, for example, Type A film used with Photofloods. The Spectra Index is 1.8. (Actually, the full Spectra Index is SI 1.8/0.9, indicating

Table II. Proposed Scale of Spectra Index Values

Kelvin Temp.	MRD	B–R Index	G–R Index
1,000	1,000	−68.8	−34.4
2,000	500	−18.8	−9.4
2,500	400	−8.8	−4.4
3,000	333.3	−2.1	−1.1
*3,200	312.5	0.0	0.0
3,250	307.7	0.5	0.3
*3,400	294.1	1.8	0.9
4,000	250	6.3	3.2
5,000	200	11.3	5.7
*5,900	169.5	14.3	7.2
*6,100	163.9	14.9	7.5
7,000	142.9	17.0	8.5
10,000	100	21.3	10.7
12,000	83.3	22.9	11.5
Infinity	Zero	31.3	15.7

both the blue–red and green–red values. Since, however, the two are identical for equivalent black-body radiation, the one index number is sufficient. If light (daylight, for example) has no black-body equivalent, the double index number must be employed. The same is true of color film when not balanced to an equivalent black-body radiation.) This becomes the index of the color film, and we also know that the lamps we are using should read 1.8 on the B–R scale and 0.9 on the G–R scale, or *within one-half unit* thereof. In other words, the Spectra B–R scale should not be below 1.3, or above 2.3. If it is, a suitable filter must be used to bring it within one-half unit of 1.8. Similarly, if the G–R scale is below 0.4, or above 1.4, a filter is needed.

Many of the light sources which do not depend on thermal radiation for their radiant energy have rapidly changing spectral distribution curves and may have wavelength regions where practically no energy is being radiated (e.g., Cooper-Hewett lamps, sodium vapor arcs, etc.) However, if sufficient energy is present in all three of the blue, green and red regions so that the Spectra Indices may be determined, then the filters indicated will make gray objects reproduce on the film as gray and will be the best all-around color reproduction that can be made with that

light and film combination, although due to the uneven distribution within the zones certain colors may reproduce differently than they appeared to the eye. This is because the response curves of the film are not the same as the eye and the photographic model of the meter is adjusted to response curves of the film so that gray may be reproduced as gray. With sources that are continuous in their radiation with no sudden peaks, the matching is quite close in all colors.

It is believed that the foregoing results in a system which is as simple to use as an exposure meter. It is hoped that manufacturers of color film and filters, and others, will use the proposed system and favor its adoption as a standard.

Until the system is adopted by others, tables of indices will be provided for the use of existing material now calibrated on the old system, or users of the meter can easily calibrate batches of film to their own particular taste.

References

1. F. F. Crandell, K. Freund and L. Moen, "Effects of incorrect color temperature on motion picture production," *Jour. SMPTE*, vol. 55, pp. 67–87, July 1950.
2. Frank Benford, "The blackbody," Pt. I and II, *G.E. Rev.*, pp. 377–382, July 1943; pp. 433–440, Aug. 1943.
3. E. Q. Adams, "X-Z planes in 1931 I.C.I. system of colorimetry," *J. Opt. Soc. Amer.*, vol. 30, no. 12, p. 657A, Dec. 1940.
4. F. Schofield, D. B. Judd and R. S. Hunter, "Proposed method of designating color," *ASTM Bull.*, no. 110, pp. 19–24, May 1941; *Ceram. Abs.*, no. 20, vol. 9, p. 212, 1941.
5. R. S. Hunter, "Photoelectric tristimulus colorimetry," *ASTM-ISCC Joint Symposium on Color, 1941*.

   R. M. Robertson and L. H. Milligan, "A readily visualized system for measuring the color of surfaces," *Amer. Ceramic Soc.*, no. 20, vol. 11, p. 387, Nov. 1941.

A Rapid-Action Shutter With No Moving Parts

By Harold E. Edgerton and Charles W. Wyckoff

The Rapatronic* camera takes still exposures of 2 to 20 μsec with a high degree of resolution. Exposure is easily synchronized with a fast-transient event, and the shutter has at least a 30-deg viewing angle with apertures in the useful range for high-speed photography. The shutter is of the magneto-optic "light valve" type, operating by the rotation of the plane of polarization of light traversing glass in a magnetic field (Faraday effect). Three polarizers, crossed at 0–90–0 deg, produce an open-to-closed transmission ratio in excess of thirty million, and removal of the magnetic field closes the shutter, allowing it to pass only one billionth of the light from the subject.

THE NEED FOR a shutter whose speed of operation is not limited by mechanical moving parts has long existed. One such shutter is the Kerr Cell type. Another type is the magneto-optic shutter. This article describes an improved model of the latter wherein several operating features have been modified.

Several motives were present when the development of the magneto-optic shutter described here was started. First, a short exposure was required. Second, a wide-viewing angle capable of accommodating the usual photographic recording methods was needed. Third, a large ratio of open-to-closed light transmission was important. Fourth, a system capable of high resolution of the optical image was desired. Fifth, a triggering system of an electrical nature where photoelectric signals could actuate the shutter was necessary. All of these objectives were realized by the shutter and control circuits of the Rapatronic camera.

With this shutter, a series of problems wherein the subject is selfluminous can be studied successfully in two possible ways. The most obvious one is the use of the selfluminosity itself for producing the exposure. Few subjects other than explosives have enough instantaneous luminosity to be photographed by their own light. A few examples are included to show the results of such applications. A second use of the shutter is to exclude the light from a luminous subject until light from an electronic-flash tube illuminates the subject for a photograph. An example among the illustrations shows a silhouette photograph of a firecracker explosion. The

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Presented on October 19, 1950, at the Society's Convention at Lake Placid, N. Y., by Harold E. Edgerton, Professor of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., and Charles W. Wyckoff, Edgerton, Germeshausen & Grier, Inc., 160 Brookline Ave., Boston, Mass.

**RAP*id *A*ction elec*TRONIC* shutter.

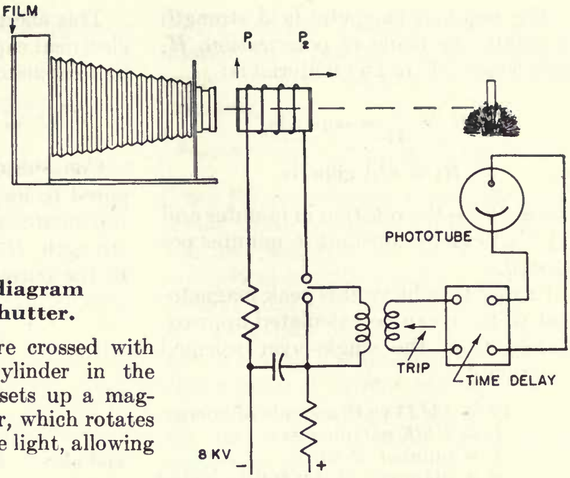

Fig. 1. Elementary diagram of the Rapatronic shutter.
Polaroid discs, P_1 and P_2, are crossed with an extra-heavy flint-glass cylinder in the center. Current in the coil sets up a magnetic field in the glass cylinder, which rotates the plane of polarization of the light, allowing transmission.

magneto-optic shutter excluded the light from the explosion but was timed to be open when the electronic flash occurred.

The "Rapatronic" shutter, as we have called it, appears to be a very useful tool for high-speed photography. Its unusually good open-to-closed ratio, its wide-angle optical system, its short exposure time, its controllability and its rugged practical nature make it a device that will find many applications on problems where bright lights and short exposure times are important.

Theory of Operation

The physical arrangement of a simple single-element magneto-optic shutter is shown in Fig. 1. Two Polaroid discs are shown at P_1 and P_2 in a crossed position so that no light is passed. Between the Polaroid discs is a glass element, or other material, which rotates the plane of polarization as a function of the magnetic field strength.

For a shutter of practical dimensions, the magnetic field strength for complete opening is very high. One practical method of obtaining such large field strengths is by the condenser-discharge method as illustrated in Fig. 1. Here electrical energy is stored in a capacitor at high voltage so that it can be rapidly discharged into the coil around the optical element whenever a signal is received, for example, from the photocell of Fig. 1.

The Faraday Effect

The plane of polarization of a beam of light in a magnetic field and parallel to the lines of force, is rotated according to the following relationship:

$$\theta = AlH$$

θ is the angle of rotation;
A is the Verdet constant;
l is the length of path of the beam in the magnetic field; and
H is the intensity of the field.

The Verdet constant of several likely materials for optical shutters is given below:

Substance	*Verdet's Constant, min/oersted*
Water	0.0130
Benzine	0.0297
Carbon disulfide	0.0441
Glass, Crown	0.0203
Flint	0.0420
Flint, dense	0.0647

The above data was measured with sodium light at 5893 A. Selected from *Handbook of Chemistry and Physics,* Chemical Rubber Publishing Co.

The required magnetic field strength to rotate the plane of polarization, H, for a length "l" of any material is:

$$H = \frac{\theta}{Al} = \text{oersteds}$$

or $$Hl = \theta/A \text{ gilberts}$$

where "θ" is the rotation in minutes and "A" is Verdet's constant in minutes per oersted.

Energy to achieve this peak magnetomotive force can be calculated approximately from the single-layer solenoid equations*:

$W = \frac{1}{2}LI^2$ watt seconds of energy

where $L = N^2dF$ microhenries

N = number of turns

d = diameter of the coil in inches

F = a constant = .0071 for $\frac{\text{length}}{\text{diameter}} = 3$. with d in inches

$$W = \frac{F}{2} d (NI)^2 \times 10^{-6} \text{ watt seconds}$$

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*Frederick E. Terman, *Radio Engineering*, p. 14, McGraw-Hill, New York (from National Bureau of Standards Circular 74, *Radio Instruments and Measurements*).

This energy can be obtained from an electrical capacitor. The energy stored in a capacitor, C, charged to E volts is:

$$W = \frac{1}{2} CE^2 \text{ watt seconds}$$

Considering the coil to be long compared to its diameter, the following approximate equation relates the field strength, H, at the midpoint of the coil to the current.

$$H = \frac{4\pi}{10} \frac{NI}{1} \text{ oersteds}$$

or $$Hl = \frac{4\pi}{10} NI \text{ gilberts}$$

and also $$Hl = \frac{\theta}{A} \text{ from before}$$

from which $$I = \frac{\theta}{AN} \frac{10}{4\pi} \text{ amperes}$$

and $$W = \frac{Fd}{2} \frac{\theta^2}{A^2} \left(\frac{10}{4\pi}\right)^2 \times 10^{-6} \text{ watt seconds}$$

This same energy is required in the capacitor assuming no losses. There-

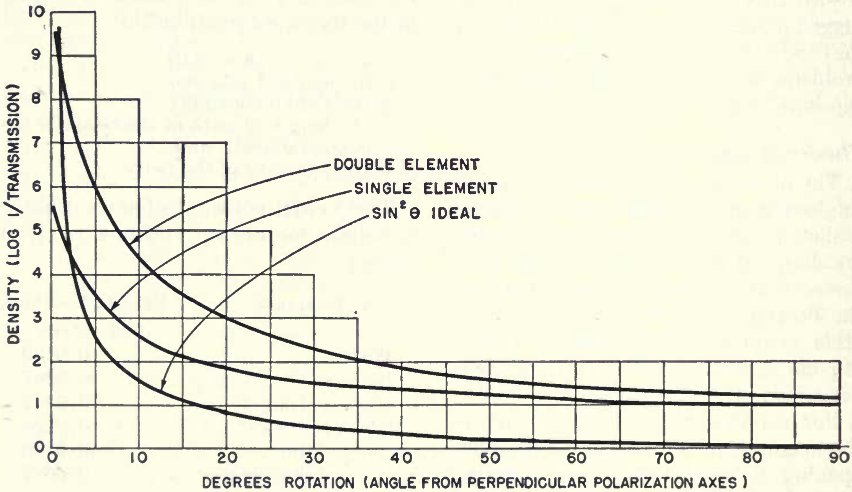

Fig. 2. Density of an ideal single shutter with sine squared relation compared to measured density of a practical single and double system. The double shutter tested has two 15-mm lengths of lead glass, three HN23 polarizers, a minus-blue and a minus-infrared filter. The single shutter lacks the center polarizer.

fore the size of the capacitor theoretically will be:

$$C = Fd\frac{\theta^2}{E^2A^2}\left(\frac{10}{4\pi}\right)^2 \times 10^{-6} \text{ farads}$$

The actual capacity required will be more than this since all the energy in the capacitor does not reach the space where the rotation occurs.

The half-cycle time of discharge of the capacitor into the shutter coil inductor is approximately:

$$T = \pi\sqrt{LC}$$

$$= FdN\frac{\theta}{EA}\frac{10}{4} \times 10^{-6} \text{ seconds}$$

and $\omega = 1/\sqrt{LC}$ radians per second

From the above equation for the half-cycle time of discharge, the duration of the opening time and the transmission can be estimated for any specific example. Note that the time is directly proportional to the number of turns in the coil and inversely proportional to the initial voltage to which the capacitor is charged.

The light transmission of a single magneto-optic shutter is a sine squared function of the rotation angle, θ, if the polarizers are ideal and crossed. The transmission of practical shutters is shown in Fig. 2. Thus when $\theta = 90°$, the transmission is a maximum. Any further rotation will decrease the light transmitted. From a practical standpoint, it is not necessary to achieve the 90° rotation since a smaller angle produces almost as much transmission. The angle for an 80% transmission is 63.5°. This maximum rotation is ample for most purposes.

From the above equations, the preliminary design for a specific shutter for a given diameter, d, or a given exposure time can be accomplished. The actual circuits will have additional inductances in the capacitors and wiring and these must be considered, especially for short exposure times.

The shutter opening cycle can be plotted as a function of the discharge cycle of the capacitor assuming no damping. Let

$$\theta_{\max} = \frac{AH_{\max}1}{60} = \frac{4\pi}{10}\frac{A}{60}NI_{\max} \text{ degrees}$$

Then the transmission can be plotted as a sine squared function of the angle for the first half-cycle of oscillation. For a practical case the current will oscillate several times. The shutter will open on each half cycle by a decreasing amount until the transient is over. A single pulse of current can be obtained if a damping resistor of the critical value for the circuit is used. Such a resistance is given by:

$$R = 2\sqrt{\frac{C}{L}}$$

where this resistance is the effective total resistance of the entire circuit. The peak current for the critically damped case is about half of the current peak for the undamped case. Therefore, the peak light transmission will be decreased when a damping resistor is inserted in the circuit.

To obtain compensation for the effect of damping, either additional capacity or a higher voltage can be used.

The connecting wires and the internal inductance of the capacitor will be very important for the above example since the coil inductance is so small. The results must be modified for such cases in accordance with electrical circuit theory.

The current in the coil will normally oscillate for several cycles if no damping resistor is used. For each current surge, regardless of polarity, the shutter will open on the peak. Each opening will be less than the preceding, since the peak current is less. A damping resistor of the critical value for the circuit will prevent these subsequent shutter openings. However, the peak current for the first peak is reduced in value unless a larger capacitor or a higher voltage is used.

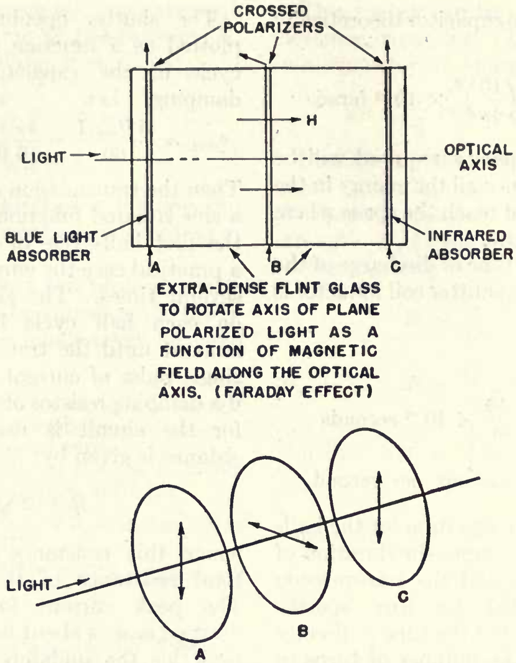

Fig. 3. Double Rapatronic shutter with three Polaroid discs and filters. The entire assembly is cemented together in a single unit. The advantage of the double combination is a very opaque closed condition permitting the photography of very bright subjects.

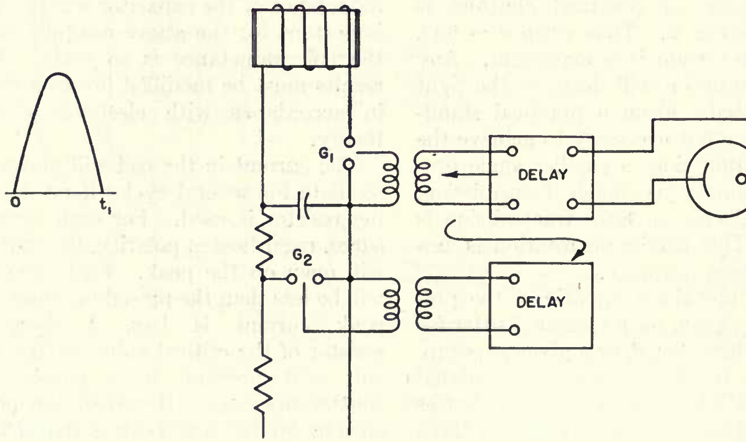

Fig. 4. The second gap, G_2, short circuits the capacitor after the first half-cycle of oscillation to limit the opening to a single operation.

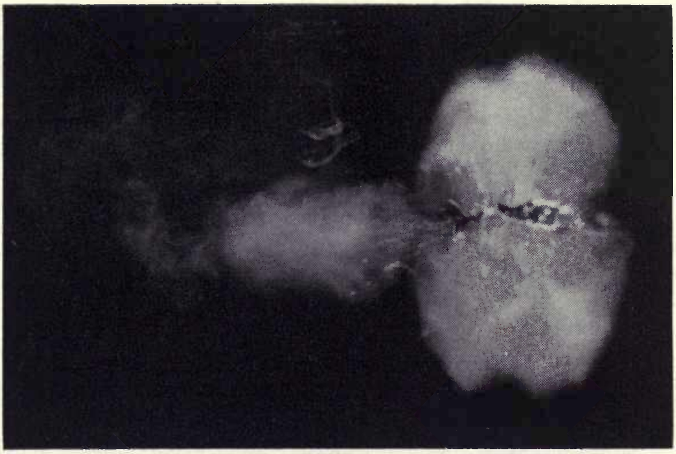

Fig. 5. A photograph of a firecracker during the explosion.

A 2-μsec electronic light source produced the illumination to expose the photograph. The light from the firecracker explosion was excluded by the use of a Rapatronic shutter.

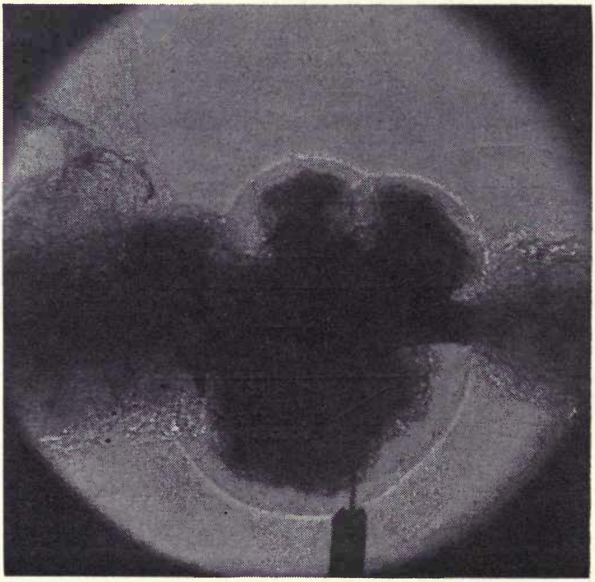

Fig. 6. A silhouette photograph of a firecracker at the instant of explosion.

The exposure time is about 1 μsec. A field lens is placed back of the firecracker to concentrate the light from a spark into the camera lens. A Rapatronic Shutter was used to exclude the light from the explosion of the firecracker.

Another method of obtaining a single surge is illustrated in Fig. 4 where a second gap short-circuits the capacitor at the end of the first half-cycle. A time delay and a trigger circuit are shown which accomplish the correct timing. The method of Fig. 4 is used when short exposures are desired.

Triple Polaroid

The use of a third Polaroid film as shown in Fig. 3 greatly helps the closed density of the shutter due to the series action of the triple crossed polarizers. However, about four times as much electrical energy is required if the total length of the glass optical path in the shutter is the same as with the two-Polaroid shutter.

Typical conditions for a three-Polaroid shutter 1½ in. long and 1 in. in diameter are:

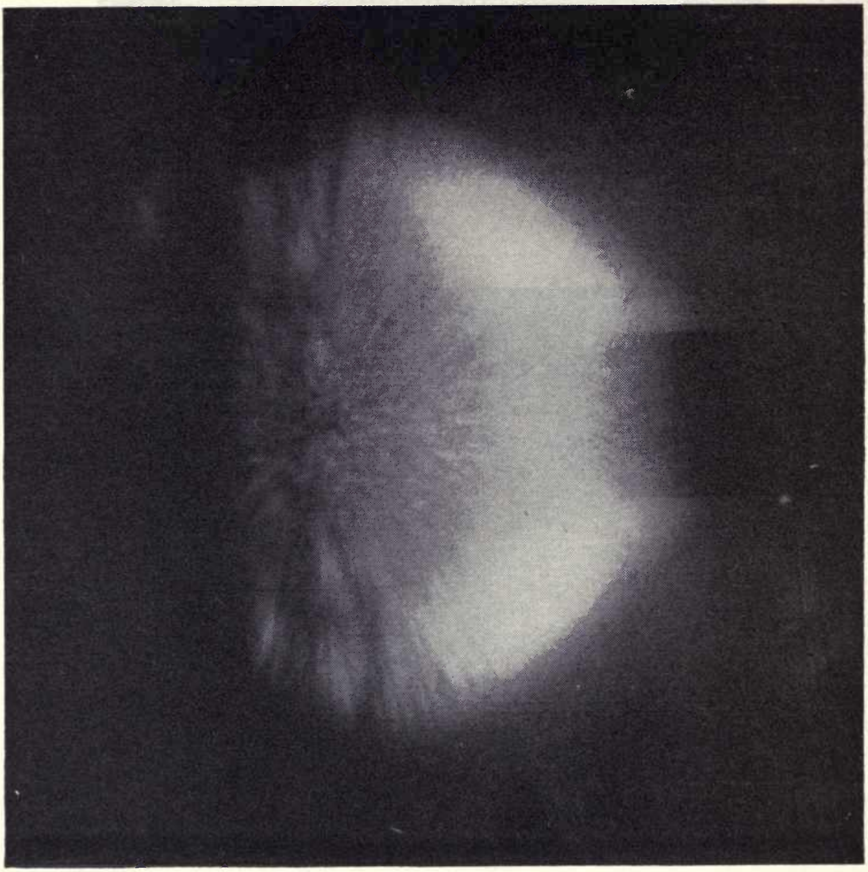

Fig. 7. The explosion of a 6-in. stick of high explosive (Pentolite). The light from the explosion was picked up by a photoelectric cell which in turn opened a Rapatronic Shutter for 4 μsec, catching the explosive wave about halfway through the stick.

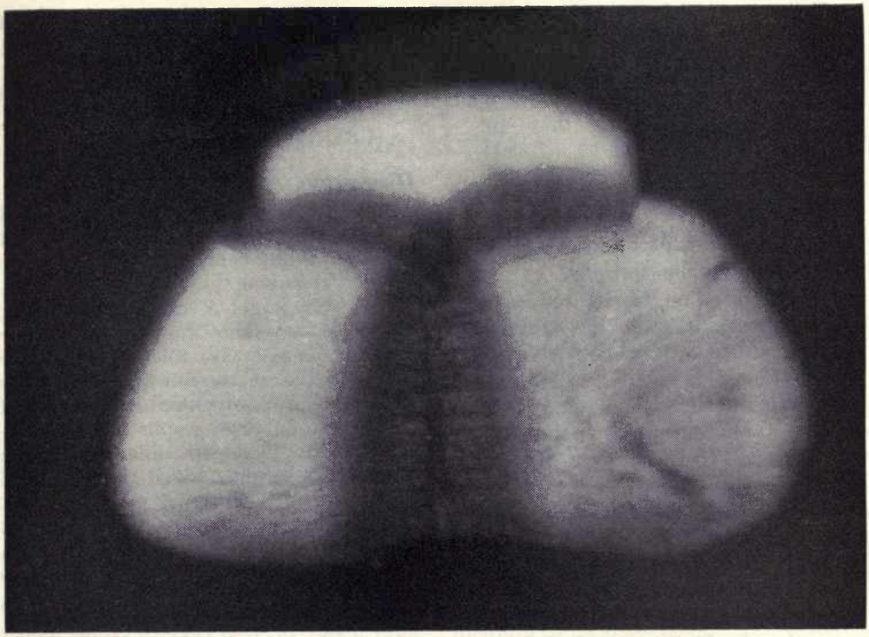

Fig. 8A. A self-exposed 4-μsec exposure of the explosion timed 15 μsec after the light triggered the phototube.

The scale is the same in Figs. 8a and 8b. Note the relatively dark areas that were the corners of the cube. This effect is the opposite of the Monroe effect.

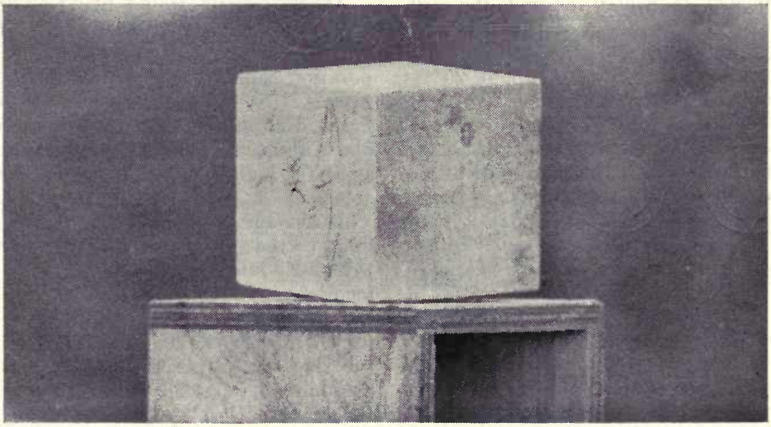

Fig. 8b. A cube of high explosive, four inches on a side, before being detonated at the center of the base.

Coil turns = 6.5
Capacity, C = 4 microfarads
Voltage, E = 8000

$$\frac{\text{Transmission } (\theta = 0)}{\text{Transmission } (\theta = 30°)} = 10^7$$

Closed density greater than 10^9
Half-cycle time = 6 μsec
Effective exposure time = 3 μsec

Examples

Two types of Rapatronic photography are shown in the illustrations:

1. Where the Rapatronic shutter excludes the light from the subject except for a brief exposure by auxiliary flash lighting (see Figs. 5 and 6).

2. Where the Rapatronic shutter exposes a photograph with light from the subject. Only subjects that emit intense instantaneous light can be studied in this manner. (see Figs. 7, 8a and 8b).

Bibliography

1. Michael Faraday, *Experimental Researches in Electricity*, vol. 3, Bernard Quaritch, London, England, 1855.
2. J. A. Anderson and S. Smith, "General characteristics of electrically exploded wires," *Astrophys. J.*, vol. 64, p. 295, 1926. (Magneto-optic shutter. A cell containing water is placed between crossed nicols. A small coil of wire connected in series with the wire to be exploded is wound around the cell. The coil is so designed that with the maximum current a rotation of the plane of polarization of about 20° is produced. With a suitable resistance in the circuit it follows that the shutter is open only near the maximum of the first half cycle. Photographs of an early stage of the explosions are reproduced and discussed briefly.)
3. J. W. Beams and F. Allison, "Differences in the time lags of the Faraday Effect behind the magnetic field in various liquids," *Phys. Rev.*, vol. 29, pp. 161–164, Jan. 1927.
4. F. Allison, "Effect of wave length on the differences in the lags of the Faraday Effect behind the magnetic field for various liquids," *Phys. Rev.*, vol. 30, pp. 66–70, July 1927.
5. N. N. Sobolev, "Controlled optical shutter," *J. Exptl. Theoret. Phys.* (USSR), vol. 17, pp. 655–660, 1947.

Discussion

Anonymous: Can the camera be focused with the shutter in the optical system and if not, does any compensation have to be made by removing the shutter?

Mr. Wyckoff: A camera employing the double-system shutter cannot be visually focused with this shutter in the optical path. A corrected focusing scale can be determined either by a series of approximation photographs or by calculation of the light-path difference due to the amount of glass added to the optical system. If the shutter is placed in front of the lens it can be very easily removed to permit a visual focus. When used in this manner with a short focal-length lens with a subject distance of several feet, compensation is not necessary.

A single-system shutter can be made so that one polarizer is physically rotatable. The shutter can thus be made to be transparent or "open" for a visual focus. The unit we are demonstrating today is the double system and cannot be made transparent for focusing because all three polarizers are securely cemented to the glass.

Anonymous: I would like to ask Dr. Edgerton if the material used is the standard polarizer produced by Polaroid Corporation similar to that for use in sun glasses.

Dr. Edgerton: No. This material is one of the newer Polaroid products known as H for high density and N for neutral color.

Anonymous: Have you found any limit to the physical size of the shutter?

Dr. Edgerton: We have not experimented with shutters larger than one inch in diameter. However, we see no reason for not making larger shutters except for the size of the electrical energy-storage equipment.

A-C Magnetic Erase Heads

By M. Rettinger

Various types of a-c magnetic erase heads of the ring-shaped type are described. After a brief mathematical treatment of the magnetic flux density required for erasing, there are given the measurements of the amount of erasure obtained with various heads used both singly and in cascade. Also included are curves showing the rise in temperature on part of two heads as a function of the 70-kc erase-current through the head.

The method of a-c erasing consists in passing the recorded medium through an alternating magnetic field which, in its central portion, has a high enough flux density to saturate the medium, and which, outside the central region, decays gradually to zero. The necessary extent of the field, both in its center and in its adjoining regions, is dependent on the wavelength of the erase frequency, in order to assure a sufficient number of magnetic reversals while the medium is passing over the eraser. This wavelength, in turn, is dependent on the speed with which the medium travels, and is given by:

$$\lambda = \frac{V}{F}$$

where λ = wavelength, inches;
F = frequency, cycles per second; and
V = speed of medium, inches per second.

Thus, for a 68,000-c erase frequency and a medium speed of 18 in./sec, the wavelength comes to 18/68,000 = 0.000265 in. In the case of a 0.004-in. long central field, every portion of the medium in its passage over the eraser is subjected to approximately 15 magnetic reversals (0.004/0.000265).

So-called ring-shaped heads are, at present, the preferred type of erasers. Like ring-shaped record and reproduce heads, they consist usually of two laminated cores forming a toroid of a sort, with a back and a front gap. The material for the laminations is most frequently silicon steel because of its higher saturation point, compared to Mumetal or Permalloy. The lamination thickness is kept very small, 0.003 in. or less, to reduce to a minimum eddy current losses with their consequent heating effects. While the front gap may assume various configurations, including that of a double gap, the back gap generally consists of a butt joint, since, on account of the large front-gap reluctance, no demagnetizing back-gap spacer is required, unlike in a recording head.

Figure 1 shows various types of ring-shaped erase heads. In this figure, (a) represents the most commonly used unit; it may be noted that in the German Magnetophon[1] the front gap had a com-

Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y., by M. Rettinger, Engineering Products Dept., RCA Victor Div., 1560 N. Vine St., Hollywood 28, Calif.

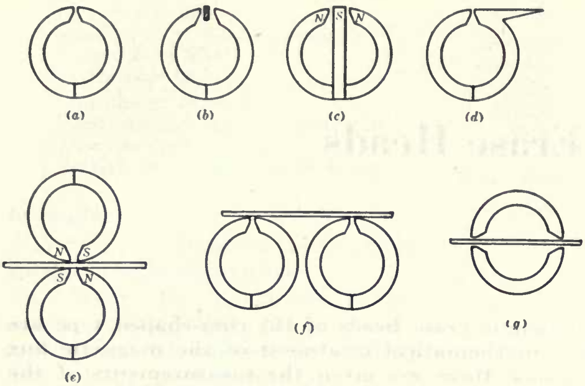

Fig. 1. Various types of ring-shaped erase heads.

paratively great length, 0.5 mm (0.020 in.). The second head shown, (b), employs a double gap,[2] consisting of a magnetic spacer sandwiched between two plastic spacers. The head pictured in (c) also has a double gap, but utilizes a magnetic center core instead of a magnetic center spacer as shown in (b). Figure 1(d) shows a head used in connection with d-c erasing. Figure 1(e) is a dual head in which the tape passes between two "standard" erase heads. In (f), the tape passes first over one and then over another erase head; this unit will be described in greater detail later. Figure 1(g) represents the "Howell head," intended for high-coercivity tape, and energized with power-line frequency current, according to patent claims.[3]

For a given front-gap length of head, two factors appear to favor a high erase frequency. The first is the increased number of magnetic reversals to which the tape is subject as it passes over the head. The second is the greater amount of self-demagnetization on the part of the little "dipoles" on the tape. The disadvantage of a high erase frequency rests chiefly in the larger eddy-current losses, with their consequent heat production and power waste, which losses increase with the square of the frequency. The flux density in the air gap is given by

$$H = \frac{\phi}{A} = \frac{\text{mmf}}{R}\,\frac{1}{A} = \frac{\frac{0.4\pi NI}{l}}{\frac{l}{A}}\,\frac{1}{A} = \frac{0.4\pi NI}{l}$$

where ϕ = flux, maxwells;
A = area of pole face, in square centimeters;
R = reluctance of air gap (considered much larger than the reluctance of the core, so that the latter becomes negligible);
N = number of turns;
I = current, amperes;
l = length of air-gap; and
mmf = magnetomotive force, gilberts.

When $N = 180$, $I = 0.075$ amperes, $l = 0.01$ cm (0.004 in.)

$$H = \frac{1.256 \times 180 \times .075}{0.01} = 1695 \text{ gauss.}$$

Investigating, at 70 kc (kilocycles), the ratio of flux density in the front air gap to that at the periphery where the tape rides, Fig. 2 was obtained. As may be surmised, this ratio decreases with increasing gap length, and has a value of 4 for a front-gap length of 4 mils. The relatively high flux density in the air gap compared to the peripheral density has led various investigators to construct erase heads in which the tape passes through the gap, as in the "Howell head," and as in the device shown in Fig. 1 (e). The unfortunate

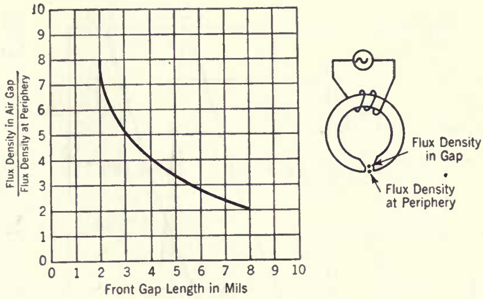

Fig. 2. Ratio of flux density in the front air-gap to that at the periphery as a function of front-gap length.

feature of these "tape-through-gap" heads lies in the relatively large gap which must be employed, since it must be large enough to pass a splice. Needless to say, such heads must be rigidly constructed if they are to be tuned, since small changes in the gap length will produce large changes in the inductance, with consequent tuning variations.

To learn something of the effectiveness of high-frequency erase heads of the ring type, a number of pairs of heads were built with different front gaps and identical inductances. The value of inductance chosen was 2 mh (millihenrys), so that two heads in series would have an inductance of 4 mh, which with a series tuning condenser was considered the largest practical value for an erase frequency of 70 kc. For a single head and short leads, the series capacity was 0.0026 μf (microfarads), and for a double head, 0.0013 μf. The back-gap spacer of all heads was made of the same material as the core laminations (4% silicon steel), and its length was equal to that of the plastic front-gap spacer. The recording medium used was Minnesota Mining Company 35-mm film, No. 115.

A number of tests made with single heads indicated that, regardless of the current supplied to the head, 70-db erasure was not possible. Surprisingly, a head with a 20-mil front gap erased about as well as one with a 4-mil gap. All heads erased 50 db with 100 ma (milliamperes), and 57 db with 120 ma, after which additional current had little effect. A head with the double gap such as shown on Fig. 1(c) provided 61-db erasure with 120 ma, after which additional current had again little effect.

When two heads were connected in cascade, however, so that the tape had to pass first over one and then over the other, the heads with the 4-mil gaps were much more effective than those with the 20-mil gaps. Thus, the "4-mil heads" provided 70-db erasure with only 70 ma, two "10-mil heads" required 100 ma, and two "20-mil heads" needed 120 ma of current for this amount of erasure.

A rather stringent erase test is made not merely to note the output meter of the reproduce amplifier during erasing, but also to listen to the monitoring speaker, with full gain in the reproduce amplifier while erasing a 1000- or 2000-c test frequency to which the ear is most sensitive. Thus the output meter might indicate complete erasure, or at least show a value comparable to that obtained when the tape is erased with a 60-c Goodell eraser; yet, when high-frequency erasure is incomplete, a trace of the test frequency can still be heard, so that the current through the head has to be increased until the signal is no longer audible. The effectiveness of all of the experimental heads was therefore judged not only by the output meter but also by the ear.

To investigate the subject further, one 4-mh head with a 4-mil front gap was built. While it was possible to erase 68 db with this head when a cur-

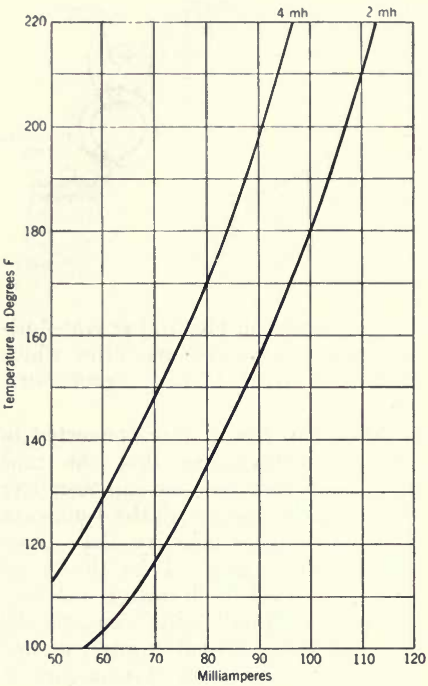

Fig. 3. Temperature rise of the head cores as a function of current.

rent of 120 ma was flowing through it, the head became undesirably hot. It may be noted that, if the chief determining factor for erasing had been the number of ampere-turns, the 4-mh head, with its 1.41 times the turns which each of the 2-mh heads carried, (Fig. 1(f)), should have erased equally well with 1.41 times the current which flowed through each of the two 2-mh heads, or approximately 100 ma (.07 × 1.41).

It was at first believed that the 4-mh head, with its larger number of ampere-turns, became saturated when a current of 100 ma or somewhat larger was flowing through it. For this reason a small exploring loop made of 0.001-in. wire was placed in front of the gap, and the output from the loop amplifier was noted as the head current was increased from 10 to 200 ma. Perfect linearity existed for this current range between input to the head and output from the loop amplifier at 68 kc; nor did the flux distribution about the gap widen or change for these current values.

For this reason it may be possible that, after first erasing the tape with a ring-type head energized with high-frequency current, there occurs a "reawakening" of the signal—a reorientation of the dipoles constituting the signal on the tape—which can be completely obliterated only by a second erase operation.

Apparently, too, some time lag must exist between the two erase operations. For this reason, possibly, the double-gap head with its 0.1-in. center core, providing a time interval of only 1/180 sec, was not as effective as the two heads in cascade, whose separation corresponded to a time interval of nearly 1/10 sec. Further study of this method of erasing appears, therefore, desirable.

A definite advantage connected with the use of two heads in cascade lies in the reduced heating of the head occasioned by the smaller current required for each head to effect complete erasure for the two. Figure 3 shows the temperature rise of the head cores as a function of current (70 kc). The curve was obtained by placing a thermocouple on the cores at the point where the tape contacts the head, and increasing the current in 10-ma steps at 10-min intervals.

References

1. J. C. Menard, "High frequency Magnetophon magnetic sound recorders," U.S. Fiat Report No. 705, Government Printing Office, Washington, D.C.
2. J. G. Frayne and H. Wolfe, "Magnetic recording in motion pictures," *Jour. SMPE*, vol. 53, (p. 225) pp. 217–235, Sept. 1949.
3. U.S. Patent No. 2,498,423 (1950).

A German Magnetic Sound Recording System in Motion Pictures

By Martin Ulner

Contrary to corresponding developments in the United States and Great Britain our starting point was to employ the magnetic-sound technique in the studio until the final re-recording on sound negative film. We did not take the necessary equipment from the optical recording system, but developed new equipment for magnetic film; and we retained the 6.5-mm magnetic tape for original recordings because of its economy.

Of the advantages of the magnetic recording procedure, that of economy is the most important in Germany. The cost of sound recording material for magnetic film is 0.23 DM (Marks) per meter, compared with 1.10 DM for an optical sound print. In the interests of economy it was decided from the beginning to use 17.5-mm split magnetic film which has no disadvantages over the 35-mm magnetic film if the film drive mechanisms are properly constructed.

Since 1945 every German film studio has made all original sound records on 6.5-mm magnetic tape and has been re-recording the good takes (in most cases immediately at the end of the recording, or at the latest on the evening of the same day) on optical film. The customary German tape recorders (of the firms AEG and Opta) are so constant in their speeds that for normal takes synchronism is maintained up to almost 60 m; the deviation for ten minutes' running time is at most four frames. Methods for synchronizing the 6.5-mm tape have indeed been developed in Germany, but have never been brought into use.

The method of working with perforated magnetic film was first introduced by the Tempelhof Film Studio in the Spring of 1950, so that now the optical sound film is employed only in re-recording on the final negative. Since then other studios have adopted the magnetic film recording method as used in the Tempelhof Studios. This procedure has proved quite successful.

All apparatus has been developed and built in the Tempelhof Studios. The development of the new equipment was not based on the optical sound recording apparatus already in use, but was developed to suit the method of working at this studio.

The Working Method

To guarantee maximum economy, all original records are re-recorded on 6.5-mm tape which costs 12.00 DM compared with 70.00 DM for the magnetic

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film for ten minutes' recording time. This method of retaining the 6.5-mm tape as a safety has an advantage in that this tape can be stored until the completion of the picture in case something happens to the magnetic film. At the same time the magnetic tapes can remain uncut and can be erased and reused after the completion of the film.

For feature pictures the print-takes (i.e., approximately one-fifth of the length) are re-recorded again, this time on 17.5-mm magnetic film, immediately after the recording as it was done before on the optical sound film. For advertising, documentary and cultural films and for dubbing of foreign films it has been found that only a single recording was needed.* One magnetic film is sufficient for the working print, for the editing, for the review and for the final re-recording print.

To simplify the cutting, the sound waves are registered visibly on the recorded magnetic film which is then forwarded to the editing room. After the recording, the magnetic film is cut and synchronized to the picture film and ready for daily running (review). After the first assembly of a dialogue reel comes the second cutting, after which it is ready for re-recording on the final negative. As already stated, in dubbing of foreign films the first magnetic film serves for the re-recording. Other magnetic film rolls contain the music and the sound effects. Optical sound reels, for example library music and sound effects, can, of course, be mixed in.

Magnetic Sound Film Recording Equipment

Figure 1 shows the magnetic sound recorder and Fig. 2, the (general) assembly of the recording equipment including monitoring. The mechanism of the magnetic sound recorder is driven by a 220-v, a-c, 50-cycle, three-phase synchronous motor. In Germany the picture camera and the sound recorder are supplied by the 50 cycles net. Synchronization is done by the old-fashioned clapstick (which has proved to be the best). Also in dubbing work the picture projector and the sound recorder are supplied by the same 50 cycles net. In the sound track the commencement of the picture loop contains so-called bloops (blumpers, clicks) or short a-c signals. These are recorded and serve for synchronizing. When shooting on location the power supply for the picture camera and the sound recorder comes from an a-c–d-c unit or inverter. In the recorder (Fig. 1) the magnetic film is transported by a 32-tooth sprocket (1). Film stabilization is controlled by a filter of two pivoted rollers (2 and 3), a large flywheel on the shaft of the primary sound drum (4) and a small flywheel on the shaft of the secondary sound drum (5). In order to keep the film from becoming mechanically damaged, the large flywheel, which is at the start coupled with the motor, is driven until it has gained full speed and is then uncoupled automatically.

The recorder and the pickup head are mounted between the two sound drums so that the recorder head is right next to the primary sound drum (4) with the playback head just behind it. The shields (6 and 7) are situated on the other side of the film. A special feature of this construction is that, when threading the film, only the head support (8) with the two magnetic heads will be lifted. During the process of reloading and rewinding, the withdrawal of the head support is not so far but that a certain amount of induction still takes place in the reproducer head so that when rewinding is in progress the signal can still be heard. This simplifies the refinding of different takes. Because the

* Dubbing of foreign films in German is done exclusively in Germany and now plays an important part in the film industry; up to 300 features are dubbed in one year in Germany.

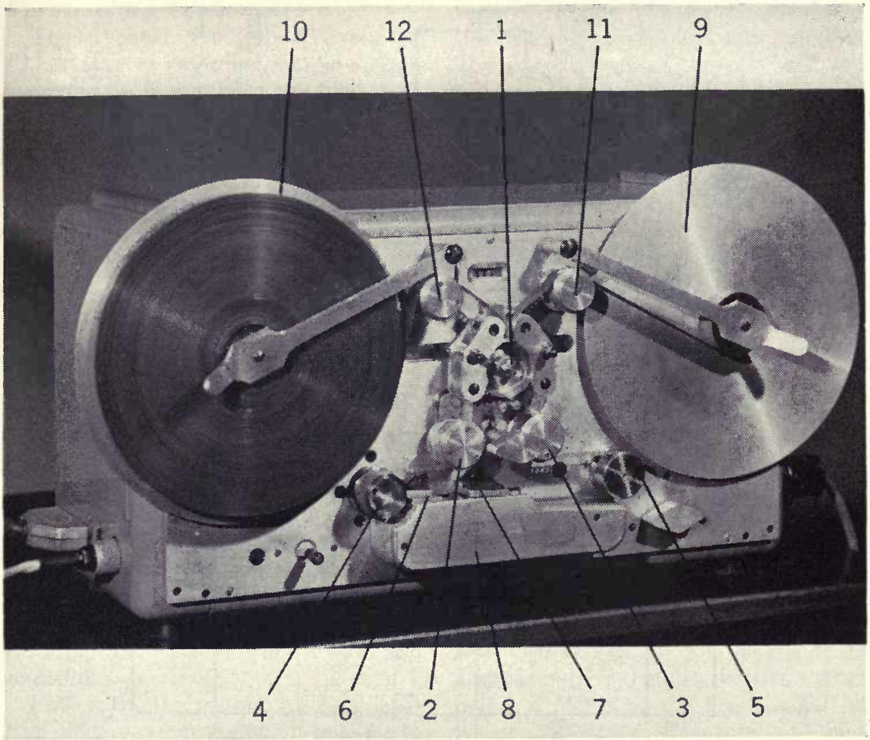


Fig. 1. Magnetic sound recorder.

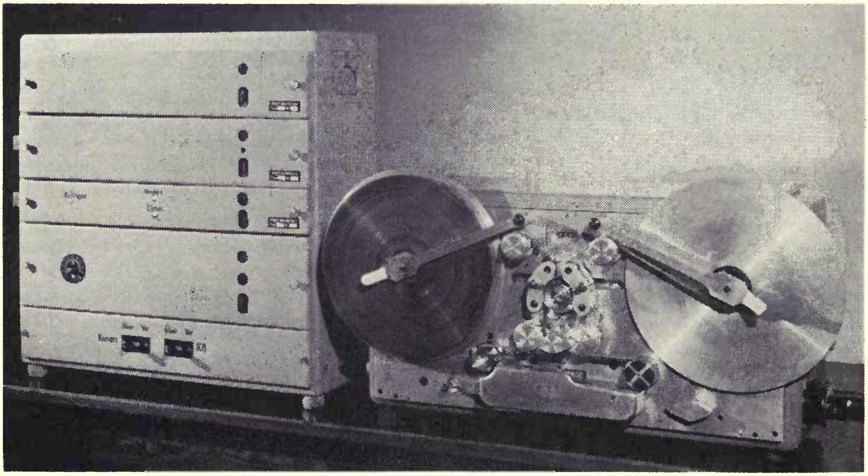


Fig. 2. Assembly of magnetic sound recording equipment.

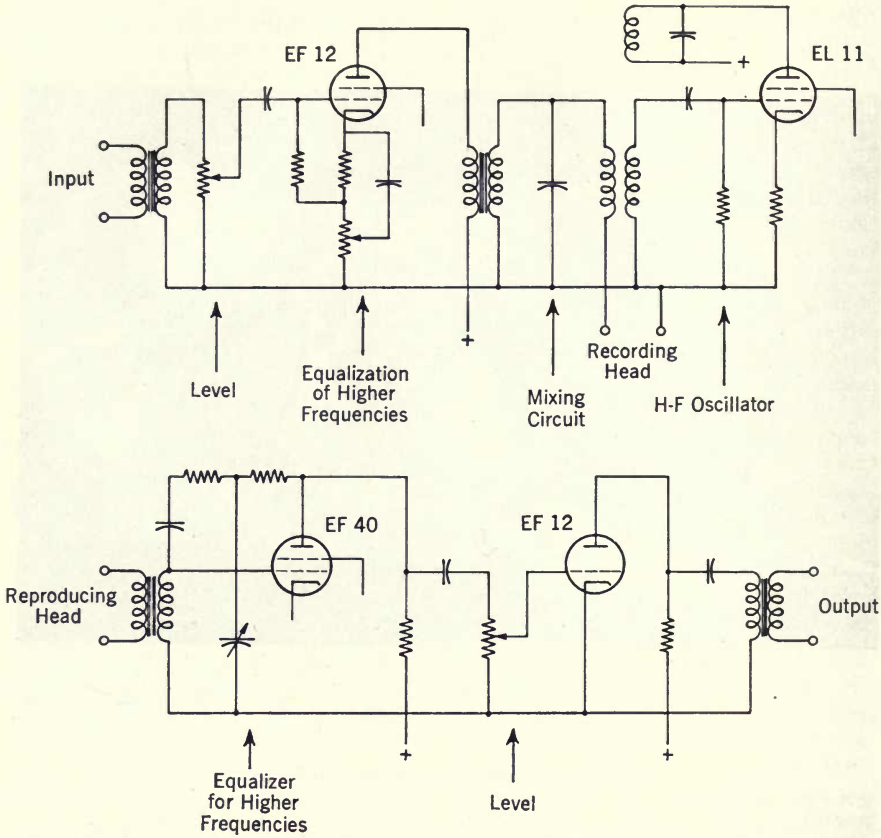


Fig. 3. Schemes of: (above) the recorder; (below) playback amplifier.

recorder does not contain an erasing head, entire rolls of magnetic film are erased for the whole studio in the sound department.

For recording and reproducing, the main motor drives the take-up spindle (9) and for rewinding, the supply spindle (10). In rewinding, the film is released from the sprocket wheel. Rewinding speed is three times greater than normal speed and should rewinding of the whole reel be desired, this can be done directly from the take-up spindle (9) over the guide rollers (11 and 12) to the supply spindle, at a speed five times greater than normal. Connected to the roller (11) is a footage indicator, by which it is possible to rewind exactly to the start of the required take. It is automatically arranged so that no recording can be done while rewinding; the recorder cannot be operated unless all the rollers are in their proper positions, and rewinding cannot be done if the film is still in the sprocket.

With this construction the recording takes place beside the sound drum, i.e., beside the spot which has the highest uniformity of speed. This results in low-amplitude modulation, while flutter is brought down to 0.06%, which is considered a satisfactory amount.

The Amplifier Equipment

The left side of Fig. 2 shows (from top to bottom): a recording amplifier, 100-mv input; a reproducing amplifier, 100-mv output; an indicator amplifier (Tonmesser); a monitor power amplifier, 5- or 20-w; and a switchboard with the "direct-playback" switch. Distortion factor of the three amplifiers is below 1%.

The recording amplifier contains a volume control and a variable compensation for losses of the high-frequency response due to the sensitivity of the magnetic film, reaching a maximum of 15 db. The reproducing amplifier compensates for the remainder of the losses of the high-frequency response of the magnetic film and the wear and tear of the reproducing head up to a maximum of 12 db. Apart from this it has the rising frequency characteristic in the lower frequencies of 6 db per octave. As is the case in German broadcasting, the lower frequencies are not raised when recording.

Both amplifiers contain a strong feedback and equalizer making it possible to obtain stability and freedom from distortion. Figure 3 shows the schemes of the recorder and playback amplifier. The output level of the playback amplifier is the same as the input level of the recorder amplifier, and when transferring from one magnetic film to another they can easily be connected. In this studio there are also recording channels for magnetic film with a frequency range which permits all parts of the recording and playback equipment, including loudspeaker, to be adjusted to give a flat response up to 15 kc.

When mixing on photographic film the frequency range is cut off at about 7 to 8 kc, due to the high-frequency distortions of the variable-area recording which is in general use in Germany. The mechanical construction of the amplifiers is based on the latest amplifier technique in Germany, consideration being given to standards and the use of high-quality parts. The lids of these amplifiers can be taken off from the front as shown in Fig. 4. The length of the amplifiers (i.e., distance between screw holes) is 550 mm, and their height 60, 95 or 130 mm. Resistors and condensers are mounted inside the chassis

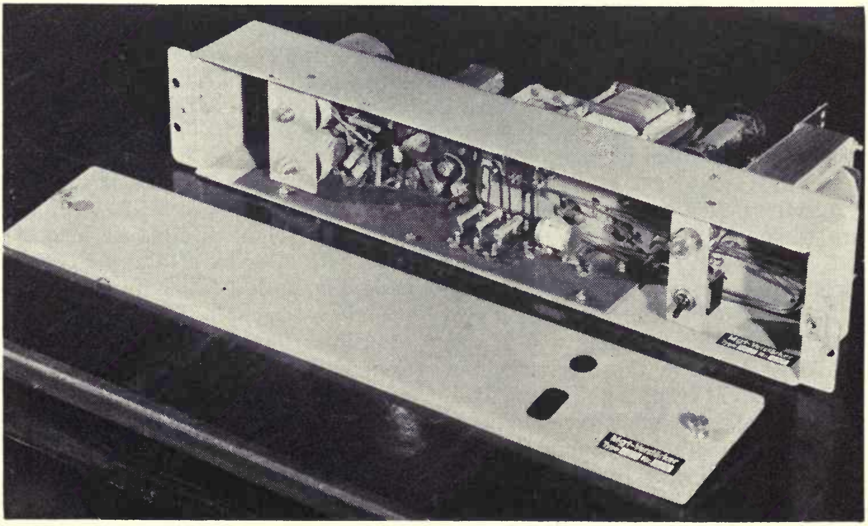


Fig. 4. Recording amplifier, with lid removed.

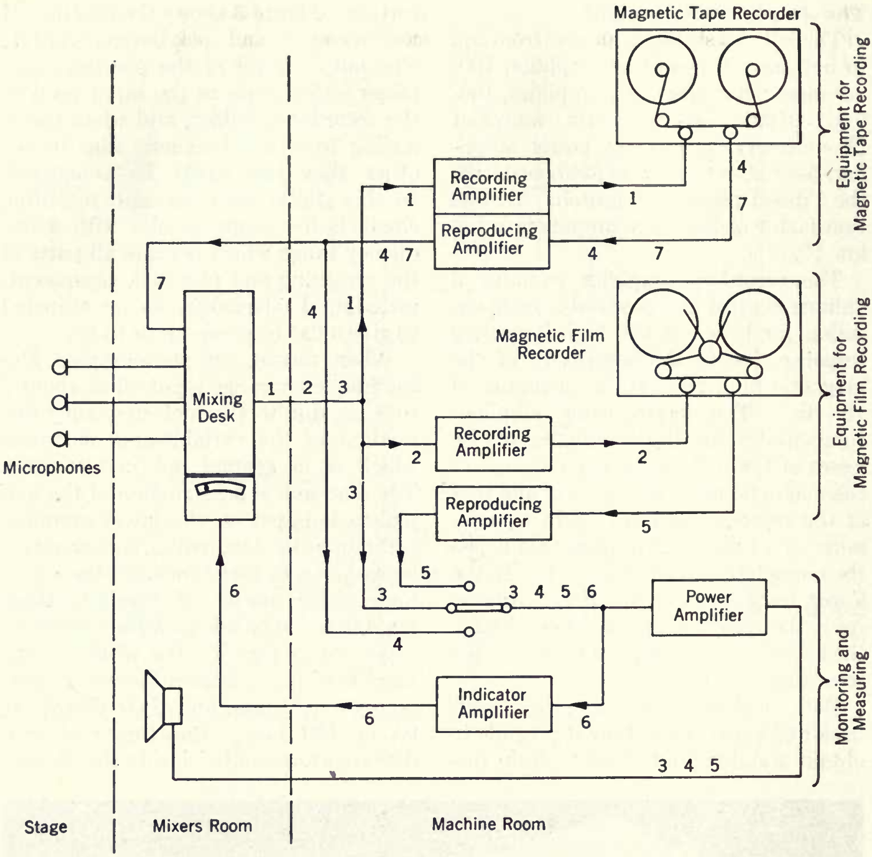


Fig. 5. Block diagram of sound recording equipment.

whereas the valves, chokes and transformers are mounted on the top. This makes it easy to get at the amplifier connections thus enabling one to measure while the amplifier is energized; it is also easy to exchange the amplifier for another one.

A layout of the sound recording system for magnetic tape and film in this studio is shown in the block diagram of Fig. 5. Microphones, of the condenser type, and the mixing table of existing photographic sound channels had to be retained. Recording can be done from the mixer on: (a) magnetic tape, path 1; (b) magnetic film, path 2; also (c) tape and magnetic film, paths 1 and 2; (d) transferring sound from tape to magnetic film, path 7 (2). When recording or re-recording, the signal can be heard: (e) directly (at rehearsals), path 3; or by (f) monitoring of magnetic tape, path 4, or by monitoring of magnetic film, path 5 (while recording). In the above examples the volume indicator in the mixer panel is always in action, path 6.

Visible Registration

Before the magnetic films are forwarded for editing and reviewing, the envelope of the sound waves is visibly recorded on a special apparatus (Fig. 6). This apparatus consists of a driving

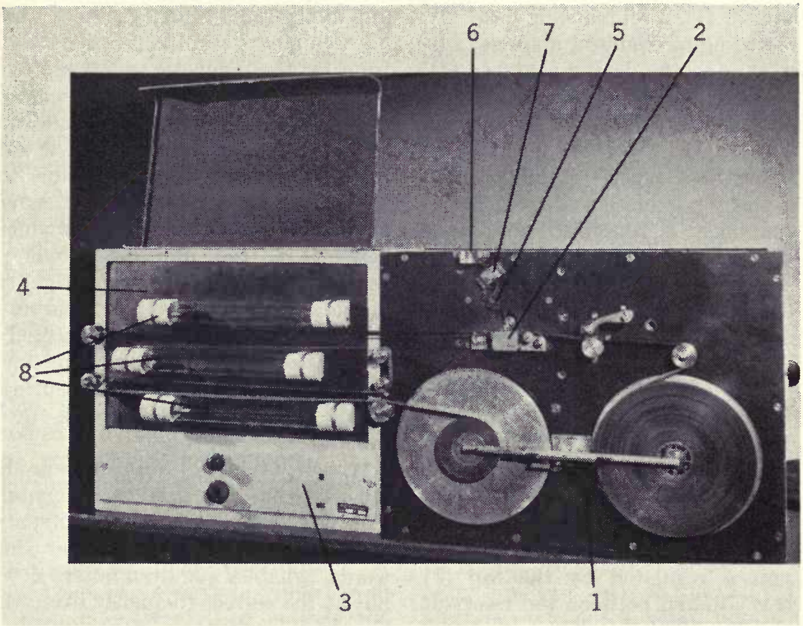


Fig. 6. Machine for adding visible signal.

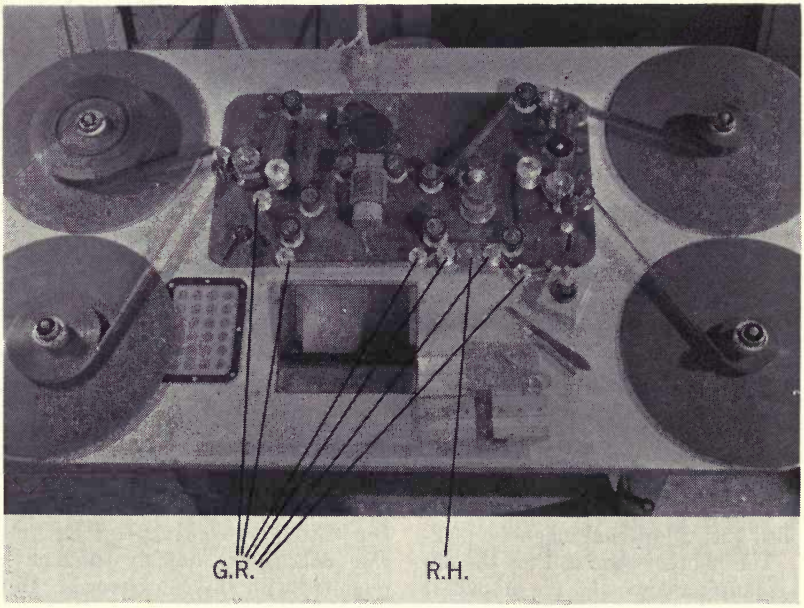


Fig. 7. Editing table with magnetic sound pickup.

mechanism (1), a reproducing head (2), the recording mechanism, a special amplifier (3) and the drying chamber (4). The speed with which the film is transported is about one-third the normal film speed. On a certain spot the reproducing head picks up the recorded signal and the induced voltage is fed to the amplifier, is amplified and rectified so that the output voltage of the amplifier shows only the envelope of the signal voltage. A peculiarity is that low signals produce a relatively higher output than loud ones. This permits even low signals to be easily recognized.

The output voltage of the amplifier is fed to a dynamic system, the moving coil of which carries a special pen. This pen is normally supplied with black drawing ink through a rubber tube (5) from a reservoir (6). The ink supply for the pen is regulated by the tap (7) which is situated between the reservoir and the pen. The pen can easily be removed for cleaning purposes. Between the writing point and the take-up spindle the film passes through a drying chamber which consists of heating tubes (8).

Film Editing

Only German editing tables (cutting desks) of the horizontal type are employed here. These contain four drums for picture and sound, normal and fast, forward and backward running, and continuous (nonintermittent) picture projection. There is a scale which shows the number of frames out of synchronism between picture and sound. Small projection is on frosted glass and large projection is on a picture screen. The American type "Moviola" editing machines are not common here and are considered uncomfortable and noisy.

All editing tables in the studio are supplied with additional magnetic pickups. The photoelectric cell for the optical pickup remains, and the amplifiers have been altered so that it is possible to hear photographic and magnetic film at the same time, i.e., the amplifier has two inputs and the necessary equalizing for the magnetic sound reproduction. In order to drive split magnetic film, the only mechanical additions necessary on this table are a few guide rollers. Figure 7 shows this table with the additions necessary for magnetic film; R.H. is the magnetic reproducing head, G.R., the additional guide rollers. Attached to the extreme right side of a few of these tables is a separate reproducing head which is connected to the amplifier; the magnetic film can be drawn by hand over this head, thus giving an additional aid for the cutting process.

At a few tables a "rotating reproducing head" has been fixed experimentally. This was originally a military invention which made it possible to hear single words, syllables and even letters slowly, but at the correct frequency even when the tape is stationary. Some cutters are so experienced that they are able to cut a film in the middle of a word without the aid of the above-mentioned two sorts of equipment.

Further aids to the cutter are the so-called click-pencil and the hand eraser. The click-pencil is a colored grease pencil containing an iron oxide powder for markings on the magnetic film, Such a pencil marking on the film produces a click sound when passing over the reproducing head and enables the cutter to make markings which can easily be wiped off when no longer needed. The hand eraser is an ordinary magnetic erasing head built into a "handle-shaped" fitting. This head is fed with strong high-frequency current which permits the erasure of unwanted noises, bloops, etc., on the magnetic film, and can, with practice, be used to swell or to restrict the sound volume of music, etc. Our cutters, in contrast to their American colleagues, quickly become acquainted with any new changes. In the case of the magnetic film each cutter was anxious to be the first one to make use of

it with the result that all the cutters are now used to this method and enjoy working with it. Other advantages for the cutter, apart from noninflammability and better sound quality, are that joints and scratches cannot be heard, and dust and fingerprints do not affect the film. All tools used by the cutters and their assistants must be demagnetized regularly before commencement of work. The same applies to the metal parts of the cutting desk, recorders, reproducers and projectors. This has become a general routine in the studio.

One copy on magnetic film transferred from 6.5-mm tape is sufficient for some productions, for instance, "dubbing" foreign pictures. Even though the film has been cut for several weeks it shows no signs of deterioration when brought to the final re-recording. A sound track can always be copied from the 6.5-mm original tape in case the magnetic film should be damaged. For security purposes some other productions prefer to take two magnetic film copies from the 6.5-mm tape. The first of these copies, which is used as a working copy, is sent to the editing room for cutting and review purposes. When the cutting of this copy is completed the second copy is cut exactly like the first one and is ready for re-recording use. This cutting is made easier by the use of visible "envelope" recording and a careful marking of the surface of the material with white ink, as is done with photographic film.

Magnetic film stock, which has already been in use, can, in general, be used again, but only as leader. This material is used by a few small productions for recording a second film on it, thus reducing the material cost by about 50%. One drawback, however, is that only the same type of material should be joined together; oblique joints have proved to be the best and it is possible to record sound signals over such a joint without any noticeable effect. When reusing magnetic film the visible record can be washed off or the new envelope record can be made with an ink of a different color.

Reviewing

Two types of projector are in use in this studio. A pickup for 17.5-mm magnetic film has been added to some of the reproducers, the pickup heads of which are mounted beside the sound drum. In other review rooms there are reproducers of the re-recorder type described below which can be interlocked with the projectors and driven synchronously. In both cases monitoring amplifiers of the previously described standard type are employed and are fed into the second input ("microphone") of the motion picture amplifier. Apart from reproduction of dailies, whole pictures with sound re-recorded on magnetic film can be reproduced by these machines without a pause (stop), thus resulting in better sound quality even when reproduced over the already existing reproducing channel.

Re-recording Equipment

No other device for magnetic film reproducing has been added to the already existing optical sound reproducers, but parallel to these, a series of eight magnetic sound reproducers were installed.

Each of these reproducers, of which Fig. 8 shows three, consists of a motor with gear, a "sprocketless pulling drive" with the sound drum and a winding-off and winding-on mechanism. The motors are fed by a d-c interlock power unit. The film-driving mechanism as shown in Fig. 9 was reconstructed from a similar optical apparatus. A high degree of uniformity of motion is guaranteed by a big flywheel on the shaft of the sound drum (1) and a sprung loopcatcher with a graphite pump (2). Here can also be found the playback head (3) mounted directly behind the sound drum. Each reproducer has a

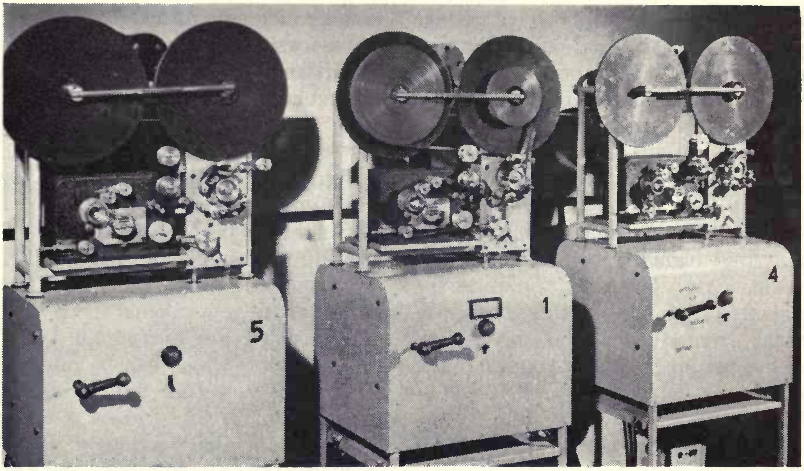


Fig. 8. A series of magnetic sound reproducers.

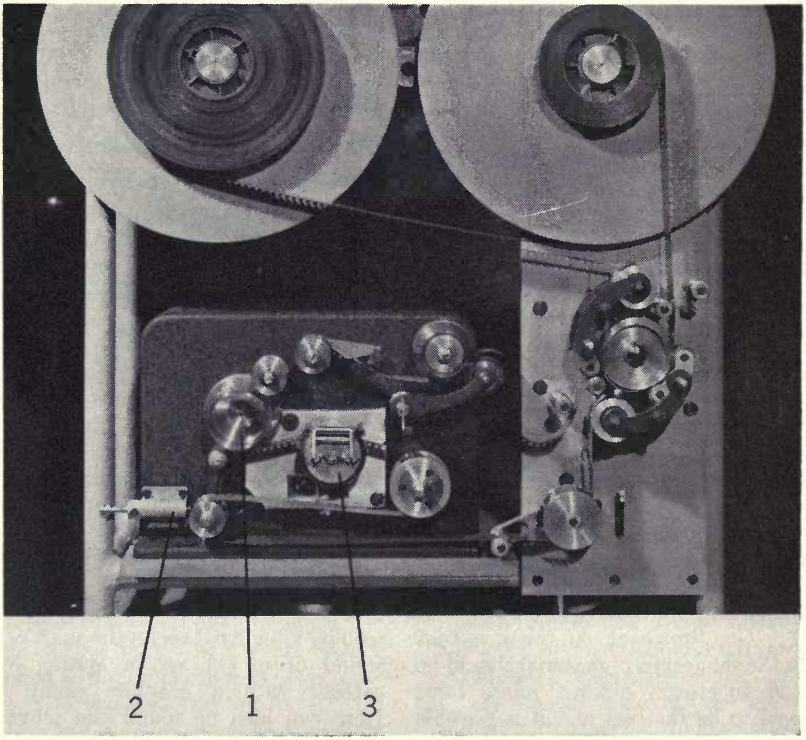


Fig. 9. A detail of magnetic sound reproducer.

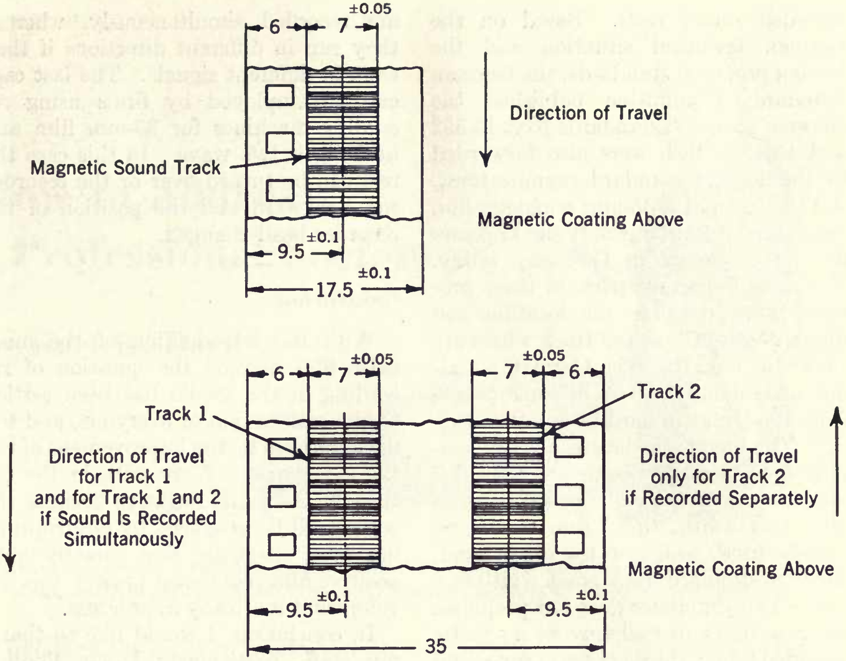


Fig. 10. Situation of sound track, from proposed standard.

standard reproducing amplifier with the magnetic sound equalizer.

Re-recording is done on magnetic film. After completion of the re-recording the reels are checked carefully for sound qualities, and the o.k. reels, one after the other, are re-recorded onto negative film. This method has the greatest saving advantage even though the process takes longer.

Magnetic Film Stock

The following four firms are the magnetic film suppliers in Germany:

1. Agfa, Leverkusen (a part of Bayer works), British Zone,
2. Badische Anilin und Sodafabrik, Ludwigshafen, French Zone,
3. Anorgana, Gendorf/Bayern, U.S. Zone, and
4. Agfa, Wolfen, Soviet Zone.

All four firms formerly belonged to the I.G. Farben and have for years also produced 6.5-mm tape. No magnetic film material whatsoever is imported. The two Agfa firms use an acetate base for the magnetic film, whereas the Badische Anilin und Sodafabrik use a base of polyvinyl chloride. The Anorgana does not produce a double-layer film, i.e., with oxide coating, but a homogeneous material containing powdered oxide. The thickness of all materials is between 135–150μ.

Standardization

Because this studio was the first to build magnetic film equipment in Germany, we were obliged, right from the start of the new technique, to fix temporary standards so that corresponding developments in the different studios and apparatus-building firms could commence from these fixed standards; of course, already existing and proposed foreign standards, British and American, were considered, in order to guarantee later exchange possibilities of magnetic

recorded sound reels. Based on the German technical situation and the foreign proposed standards, the German Standards Committee published the German proposed standards Nos. 15,552 and 15,553 which were also forwarded to the foreign standard organizations. A 17.5-mm and a 35-mm magnetic film were standardized but only the 17.5-mm film is employed in Germany today. The most important parts of these proposed standards are the location and dimensions of the sound track which are shown in Fig. 10. The German standard unavoidably differs in some points from the U.S. standard because:

1. The magnetic heads usually employed in Germany have a width of 7 mm and as there was no necessity to alter this width, this 7-mm track was standardized, while, on the other hand, the U.S. standard has a track width of 5 mm. This difference does not prejudice the possibility of exchange of magnetic recorded films; the distance of the sound track from the edge of the film is 6 mm in both standards.

2. On the 35-mm film only two tracks are standardized. Both tracks run in the same direction if they contain the same signal or stereo sound, i.e., if they are recorded simultaneously, whereas they run in different directions if they contain different signals. The last case can be employed by firms using recording machines for 35-mm film and utilizing it two ways. In this case the reel can be turned over or the recorder run backward and the position of the recorder head changed.

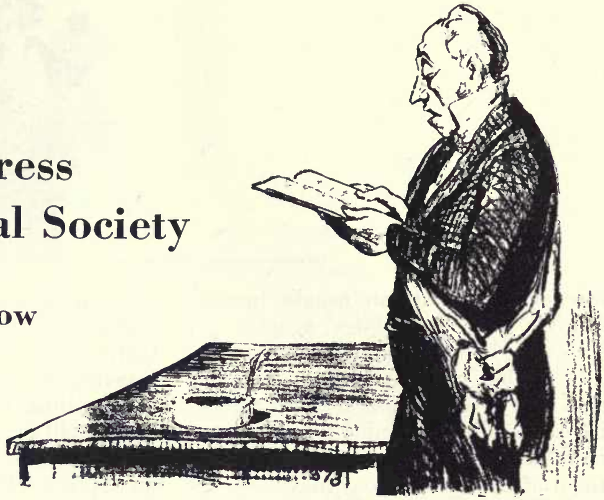
Conclusion

With the introduction of the magnetic film method the question of recording in the studio has been settled to the satisfaction of everyone, and the next step will be the improvement of the theater copies. There will, in the future, be no sound negative because the copies will be produced by electroprinting from magnetic film directly onto positive film (combined print); this development is already in progress.

In conclusion, I would like to thank my staff, particularly Horst Redlich and the mechanics in the workshop of Mr. Albrecht, for their assistance and cooperation in the various problems in the construction of mechanical devices and in the development of the amplifiers.

How to Address a Professional Society

By Karl K. Darrow



Does everyone head for the corridors when you rise to read your paper? If so, the Secretary of the Physical Society wishes to have a word with you.

Consider an actor in a hit show on Broadway, and contrast him with a physicist addressing the American Physical Society.

The actor has all the advantages. He is speaking lines written for him by a master of the art of commanding the interest of an audience (remember that we are postulating a hit show). He has a gift for acting, and also a long experience in the art; otherwise he would not be in the cast. Even so, he is not allowed to speak his lines in any way that occurs to him. Every phrase, every inflection, every gesture, even the position that he is to take on the stage, has been tested or even prescribed by a professional director, who does not hesitate to give him mandatory instructions, or even to alter the lines if they seem ineffective.

One might assume that assured of such splendid collaboration, the dramatist would write a play two hours long without a break, and the manager would be content to offer the play in a barn with benches for the seats. This is apparently not the view of those who are experienced in such matters. Ample intermissions are provided, and an act which runs for as much as an hour is sufficiently rare to cause the critics to mention it. Usually the theatre has comfortable chairs and is well ventilated or even air-conditioned. All this is provided to induce people to come to a play for the apprehension of which, with rare exceptions, no intellectual effort is demanded.

Now consider the physicist. He has thought out his own lines, and is not always proficient in this not altogether easy art. He has little or no training in the art of elocution, and no director has rehearsed him. His subject requires a considerable amount of mental effort on the part of his listeners. The

Reprinted from *Physics Today* for February 1951 where it was published as "How to Address the American Physical Society," by Karl K. Darrow, for 33 years a physicist on the staff of Bell Telephone Laboratories in New York City, and for the last ten years Secretary of the American Physical Society at Columbia University.

listeners themselves are usually uncomfortable and sometimes acutely so. This may be because the chairs are uncomfortable, or because the room is hot and stuffy, or because the programme has already been running for an hour or more without a break; or two or all three of these conditions may exist together. Laurence Olivier or Helen Hayes might well quail at the prospect of having to sway an audience under such conditions. Under these highly unfavorable circumstances, does the physicist strive to put on a reasonable facsimile of Olivier or Hayes? It may be conjectured that frequently he does not, because of the popularity of the saying than when a meeting of the American Physical Society is going on, the members are in the corridors or on the lawn instead of listening to the speakers. People with tickets to *South Pacific* are not standing around in Forty-fourth street when the curtain is up.

Can anything be done to amend this situation? Very little, I am afraid, but the following suggestions point in the right direction.

1. *Speak loudly enough to be heard in the remotest part of the room.* Some people sincerely believe that their voices are too weak to achieve this. No doubt this is sometimes the case, but I venture to believe that most of them are wrong. In my youth I was constantly reproached for speaking too faintly, and I thought that I could not help it; experience proved me wrong. I do not think that I could manage a speech in the Metropolitan Opera House without an amplifier, but a physicist is not likely to be asked to speak in so large a hall, and if he were he could count on the presence of an amplifier. In a hall seating three hundred persons or fewer, the amplifier ought to be unnecessary except in pathological cases. If there is an amplifier, do not expect it to transform a conversational tone into a loud one. It is better to go to the opposite extreme, and pretend to yourself that the microphone is not there, even though you are speaking directly into it.

The trick recommended by those who instruct speakers is to look at and speak to the people in the rear row. This is often made difficult by the fact that some of the prominent people in the audience are sitting in the front rows; this is particularly common in University colloquia. If this situation exists, ignore it. If Fermi is sitting in the front row and Joe Doakes in the rear row, speak to Joe Doakes, Fermi will hear you.

2. *Write out your speech in advance, and commit it to memory.* I have heard only one objection (from the viewpoint of the audience) raised against this procedure, and it seems to me groundless. It has been contended that a written speech is dull and lifeless; the implication is that an unwritten speech glitters with sparkling impromptus. But the presence of a manuscript need not prevent the speaker from substituting a sparkling impromptu for something that he has written; and if the impromptu fails to occur to him, the manuscript is there to carry him along. Of course, it is

". . . in the corridors . . ."

possible to memorize a speech without writing it out; this is recommended to those who hate to write. It is a fact that a good speech is likely to be looser in texture than a good article. No difficulty will arise from this cause if the speaker remembers that it is a speech that he is writing.

There are some who think that it is better to hear an unprepared physicist groping for what he wants to say than a prepared physicist saying what he wants to say. It would be fascinating to see this theory given a trial by the Sadler's Wells Ballet, but nobody ever will. For an advanced student of the dance it may be instructive to see a dancer fall on her face, pick herself up, and resume her part in the ballet; but for practically everyone else it is acutely embarrassing.

3. *If you cannot memorize your manuscript, read it aloud.* This bit of advice will probably be resented, for we have all suffered from dreary speeches poorly read. There is, however, no compelling reason why a manuscript should be poorly read. Lady Macbeth has to read a letter aloud in an early scene of the play; it is one of the high points of the drama. More than thirty years ago Ethel Barrymore read a letter aloud in such a way that it is still remembered by elderly playgoers, though the play itself is forgotten. The trouble is largely that most readers glue their eyes to the manuscript for seven-eighths of the time, lifting their eyes from time to time to steal a glance at the audience as though to make sure that it is still there. Reverse the ratio. It is easy to keep your eyes on the audience during seven-eighths of the time and look at the manuscript during the other eighth. For a manuscript which you have composed yourself, it should be extremely easy. Try it and see.

4. *Situate your topic in the general framework of physics at the beginning, and summarize your conclusions at the end.* Even in a ten-minute paper, a minute at the beginning and a minute at the end are not too much to reserve for these purposes. Do not fear to repeat your main points. I shall have more to say on repetition near the end.

5. *Time yourself.* The members of the American Physical Society are now pretty well trained in the art of giving ten-minute papers, but longer ones are still apt to overrun. This is particularly serious when the closing bell rings when the speaker still has five minutes to go, and these five minutes comprise the conclusions which are the incentive for the paper. The speaker naturally does not want to omit the climax of his speech, and the chairman is seldom ruthless enough to insist.

This is when having a manuscript is particularly useful. Timing-marks can be inserted at the end of each page or along the margin, and the speaker (who should constantly be looking at his watch) will then know when he is running behind and will be able to catch up by leaving out relatively dispensable passages. One hundred and thirty words a minute, or say two-and-a-half minutes for a double-spaced typewritten page, is

fast enough. In the timing, allow for twenty seconds or thereabouts of silence just after you make each of your difficult points. These gaps will give the audience a chance to think about what you have said; there are no laws requiring a speaker to be talking *all* of the time at his disposal. The difficulty in timing is greatest when the paper involves blackboard work or slides. Rehearsal is necessary in such cases, and is worth the effort.

6. *Aim your discourse toward the average of the audience, not toward the topmost specialists.* Too many young theoretical physicists speak as though they were instructing Oppenheimer; too many bandspectroscopists, as if they were addressing Mulliken; too many solid-state physicists, as though the audience consisted of Seitz—and so it goes. This is not quite so flagrant a fault as it was in the days before the meetings of the Society splintered into simultaneous sessions, each attracting its own coterie of specialists; but it is still an error, and anyone who avoids it is doing his bit toward the all-important end of keeping physics from breaking up into a horde of narrow specialties.

There is one specious argument for the procedure which I am deprecating here. The young man may think that the topmost specialist is also the prime job-giver, and therefore is the man whom it is urgent to impress. But in the first place, it seems plausible to suppose that the topmost specialist forms his opinions of the neophytes from their writings and from personal contacts; and in the second place, the job-giver in the audience may be, say, some chairman of a department of physics whose own specialty lies elsewhere, and who is going to assess the young man by his lucidity and not by his profundity. If these entirely reasonable suppositions are correct, the young man is doing himself a disservice by speaking as though he were addressing exclusively those who know more than he.

7. *The problem of the blackboard.* This is one of the toughest of all problems. and here the theatre is of no use. I have never seen a play in which an actor had to write on a blackboard. I think that an actor would write on the blackboard without saying a word, and then turn to the audience and speak. For a physicist the psychological inhibition against doing this is quite invincible, but at least the attempt should occasionally be made. He can at least avoid the tendency to drop the level of the voice while addressing the blackboard. There are, however, two faults at the blackboard which can often be avoided.

One should write his symbols large enough so that they can be read from the back of the room. I hope I never forget the shock which I once experienced when, having finished what I had fondly supposed to be a good lecture, I went to the back of the room and found that nothing I had written could be read beyond the middle rows. Sometimes the speaker finds the blackboard to be much smaller than he had reasonably counted on; in such a case he has to choose between altering his presentation and confining his effectiveness to the people in the nearer rows. Sometimes, of course, either the chalk or the blackboard is impossibly bad; the speaker is then helpless unless he is good enough to revise his plans and do the whole speech without the blackboard. One ought also to write his equations in the order in which he speaks them, instead of putting each in the nearest convenient empty spot and dabbing with the eraser to make more empty spots, so that at the end the board is littered with incoherent symbols. One should know in advance just how the board will look at every moment during the discourse, and at the end of the talk the board should carry all of the principal equations arranged in logical order. I am afraid that this is a counsel of perfection.

8. *The problem of slides.* Most people who show slides at all show too many

and show them too fast. (I suspect that this is often because the speaker has prepared too long a speech and tries to compensate by racing through the slides.) Rare is the slide which can be properly apprehended in less than thirty seconds, though exceptions do occur. It is impossible to assign a rigid maximum to the number of slides which can be shown effectively. I suggest seven for a ten-minute paper, but I make exception for the cases in which the argument is shown on slides instead of on the blackboard. The one advantage of the blackboard over slides is that the overfast speaker is obliged to slow down as he writes; this advantage can be shared by the slides if the speaker will give them time enough. There is much else excellent advice to be given about slides, but it has all been said by J. R. Van Pelt in the July 1950 issue of *American Scientist.* This should be required reading for all physicists.

9. *The problem of the "jargon."* Some people ascribe the difficulty of understanding science to what they call the "jargon." This seems to imply that scientists use long technical terms out of perversity, when they could just as well use short familiar words. This is absurd. If I am giving a speech on a subject involving entropy or a synchrocyclotron, less than nothing will be gained if I avoid the word *entropy* or the word *synchrocyclotron* by some cumbrous periphrase or by some vivacious popular word which does not mean the same thing. Entropy is entropy and a synchrocyclotron is a synchrocyclotron, and there is no synonym for either. On the other hand there is nothing to prevent me from giving a brief definition of either. It does not have to be a complete definition: I may say that entropy is $\int dQ/T$ between certain limits of integration, or that a synchrocyclotron is a cyclotron in which the frequency is modulated so as to overcome the obstacle arising from the change of the mass of the nuclei with their speed. It may be objected that a person who does not know in advance what these words mean is unable to profit by the discourse. This view fails to take account of the fallibility of human memory. The listener may have forgotten what the words mean; he may even be able to recover the meanings during a few seconds of groping, but during these few seconds the speaker will go so far ahead that the gap cannot be closed. I have often observed that the place at which I lost contact with a speaker was the place at which he used a word which made me stop and ponder. It seems worthwhile to try to avoid such dangers.

There is a sense in which physics is afflicted by what may be called jargons, though I should prefer to call them private languages. This is a phenomenon of recent years. Formerly physicists were few and far between, and one who did not make himself understood to his fellow-physicists a thousand miles away did not make himself understood to anybody. Nowadays many physicists do team work in large groups. In every such group a private language arises, characterized first of all by omissions. Relevant facts and even essential steps in an argument can safely be omitted within the group, because everybody knows them. In addition, the group invents all sorts of abbreviations, nicknames, and pet names for such things as parts of an apparatus, cosmic-ray tracks of various aspects, irregularities in crystal lattices, phenomena of hole-conduction, and even basic concepts of physics. No dictionary contains these terms; they travel by word of mouth, and often they do not travel fast enough. When they are spilled out before a meeting of the Society, disaster may ensue if they are not defined. Facility of travel and interchange of personnel are doing much to retard the development of a Berkeley language, an Oak Ridge language, a Murray Hill language and the like; but the danger is always with us.

10. *Style.* The concept of style being vague and the teaching of style lying in the province of another profession, I confine myself to two remarks.

Textbooks of style advise the writer, and therefore inferentially the speaker, to strive for a proper proportioning of long words with short, and (what often comes to the same thing) of words of Greek, Latin, or French origin with words of Saxon origin. Now, a scientific article is perforce overloaded with words which are both long and of Greek or Latin origin. This suggests that whenever the speaker has an option, he should choose the short word over the long and the Saxon word over the Greco-Latin. If a sentence contains such words as *ferromagnetism* or *quantization* or *electrodynamics*—not to speak of the atrocious *phenomenological*—it is really amazing how much the sentence will gain in grace and fluency if all the other words are colloquial and short. This policy also tends to bring out the necessary long word in bold relief.

It is said that the style of our forerunners was largely formed by the King James Bible, and that the style of our contemporaries is influenced by the *New Yorker*. Neither of these publications can have much influence on those who do not read them. The suggestion is that physicists should not confine their reading to their professional literature. Read novels; read poetry; read essays; read history as written by notable writers; read Winston Churchill and read Rebecca West—or if you simply will not go beyond the writings of scientists, read the Braggs and Eddington and Jeans and Bertrand Russell. Failure to observe this precept is partly accountable for the fact that it is seldom possible to tell from the style of an article in the *Physical Review* who wrote the article, and for the further fact that scientists who try to write something for the general public so often do it badly.

11. *A suggested experiment.* I have proposed, *inter alia*, that a speaker should speak slowly, show his slides slowly, define his private-language terms and repeat his main points. To anyone who deprecates this advice I suggest the following experiment.

Choose an article in *Physical Review;* let it be in your own field if you will, lest the result of the experiment be too frightful. Sit down in an uncomfortable chair, and read the article—but read it according to the following prescriptions. Read straight through from beginning to end at the rate of 160 to 180 words per minute. Never stop to think over anything, not even for five seconds. Never turn back, not even to refresh your memory as to the meaning of a symbol or the form of an equation. Never look at an illustration until you get to the place where it is mentioned in the context; and when you get to that place, look at the illustration for ten or fifteen seconds and never look at it again. If this is not the way that your listeners will apprehend you when you give a paper, you are an outstanding speaker.

Illustrations by H. Daumier, courtesy New York Public Library

High-Diffusion Screens for Process Projection

By Hugh McG. Ross

I. Requirements of Translucent Screens

One essential difference between front and back projection lies in the manner in which light leaves the screen and enters the lens of the camera or the eye, and to consider this we must imagine the film or slide removed from the projector and the blank screen illuminated. The distribution or unevenness of the brightness of the screen which is then seen will still be present when the picture is superimposed upon it, In back projection very little light is reflected; most of it passes through the screen and is scattered to some extent. The effect is shown diagrammatically in Fig. 1. The angle between the incident ray and the screen makes little difference in the shape of the curves. However, when the screen is photographed or observed from the camera position, the intensity of the light coming from the center of the screen is greater than the intensities from the edge and corners. This explains the existence of the well-known "hot-spot" characteristic of back projection.

The magnitude of the nonuniformity of the screen brightness depends upon the angle through which the light must be diffused in passing from the projected light beam to fall on the camera lens. This angle is the sum of the angles from the camera and projector lenses. The values of such angles at the corners of the screen for various projector and camera lens focal lengths is shown in Table I. For the great majority of process shots the total angles

Abstract by F. B. Berger of a paper by Hugh McG. Ross, published in *J. Brit. Kinemat. Soc.*, vol. 16, no. 6, pp. 189–199, June 1950.

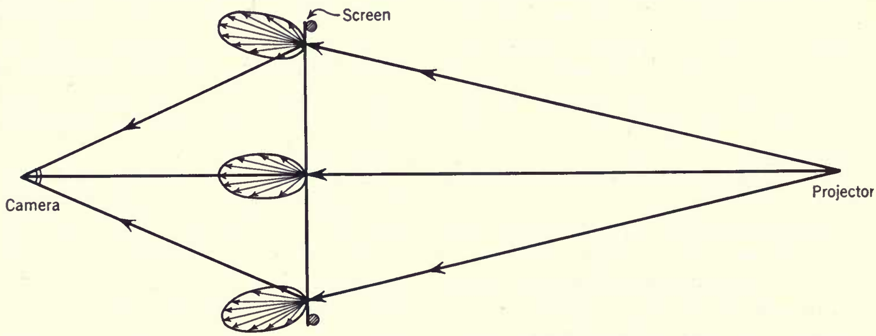


Fig. 1. The way in which light is scattered on passing through a diffusing screen.

The length of each arrow represents the intensity of the light in the direction of the arrow, and the polar curve joins the tips of the arrows.

Table I. Camera and Projector Lens Angles

35-Mm Camera Lenses								
Focal length, mm...	25	28	35	40	50	75	100	
Corner angle, deg..	28.6	25.9	21.2	18.8	15.2	10.3	7.8	
35-Mm Process Projector								
Focal length, in.....	2	3	4	5	6	7	8	9.25
Corner angle, deg...	16.4	11.1	8.4	6.7	5.6	4.8	4.2	3.6
Still Projector, 3 × 2.2 in.								
Focal length, in.....	6.4	8	10	12.5	14	16	18	22
Corner angle, deg...	16.2	13.1	10.5	8.5	7.6	6.6	5.9	4.8

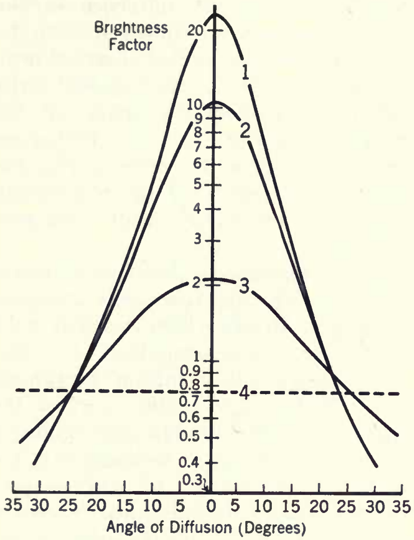


Fig. 2. A preferred way of drawing the polar diagram.

Curve 1: measured at corner of typical graded screen in normal use.
Curve 2: measured at center of the same screen.
Curve 3: new high-diffusion screen.
Curve 4: nominal performance of good front-projection screen for comparison.

range from 15° to 30°. An examination of the data shows that the camera lens, being generally of shorter focal length, contributes far more than does the projector lens to the total angle. A convenient rule of thumb is that the projector throw should be about twice the camera throw, and it is unnecessary to make the projector throw greater than this.

For quantitative considerations the data are more conveniently presently in the Cartesian form, as in Fig. 2, in which brightness is plotted logarithmically against angle for several screens. The measurements were made by projecting a steady light on the screen and observing the brightness of several test areas of the screen from different angles, using either a Morgan Reflectometer or the S.E.I. Visual Photometer. The units used represent the brightness which would be obtained if the incident light were reflected back by a Lambert surface, a perfectly white matte reflector, and may be termed the "brightness factor."

If a uniform screen is used, made with the same thickness of diffusing material all over its area, the brightness across the screen, as observed from the camera position, is rather similar to this polar curve. If, on the other hand, a nonuniform or graded screen is used, made with additional diffusing material near its center, the complete brightness distribution curve cannot be assessed so easily. For example, the

two upper curves of Fig. 2 are for the best type of graded screen hitherto available. These curves show that if the projector side of the screen is uniformly illuminated, the center is fifteen times brighter than the corners at 25°. The hot-spot produced in such a case may be partly overcome by placing metal discs in the center of the light beam. These discs reduce the intensity of the light falling on the center of the screen, but with skilled use they need not reduce the intensity of light falling on the edges and corners. They have the serious practical disadvantages that it takes considerable time to position them, and the movement of the camera is restricted.

Curve 3 of Fig. 2 illustrates the new high-diffusion screen. The first important point is that the center is only two or three times as bright as the corners. This overcomes the hot-spot effect, and considerable experience with these screens has shown that the great majority of back-projection shots, including Technicolor, may be thrown up on the screen without any hot-spot being noticeable. This curve is found to be better than an even more uniform one.

The second important point is that the brightness of the corners of the picture is as great as with the older screens, so that no increase of camera exposure is required.

The new screen possesses several distinct advantages from the practical point of view. These are:

1. The camera may be moved parallel to the screen surface without having the average screen brightness or light distribution change to any objectionable degree.

2. The camera may also be freely moved in a direction normal to the screen surface.

3. The freedom in panning and tilting the camera without objectionable changes in average brightness or uniformity is considerably greater with the new screen.

4. The accuracy with which the optical axis of the projector is aligned with the camera axis and with the screen is much less critical than with older screens.

All the effects described are independent of the scale of the setup. Larger pictures require simply greater light output from the projector to maintain the same brightness as for the smaller picture. Even the definition is not affected.

The best method of making light measurements on a diffusing screen is to use a narrow-angle photometer while standing at the camera position, the S.E.I. Visual Photometer having proved particularly suitable.

II. Experimental Study of Screen Properties

A systematic study has been made of diffusing materials for screens with a view toward finding out which qualities are important for the quality of the screen and also which other qualities have no useful effect. Both the diffusing material and supporting material must be colorless and should be unaffected by age, weather conditions or washing. The base material is preferably a plastic. The most suitable are ethyl cellulose or ethyl acetate. Finely powdered optical glass was chosen as a satisfactory diffusing material.

Another important factor is that the straight-through brightness factor be not too great (to reduce hot-spot) and that the brightness factor at angles of about 25° be as much as possible to ensure high corner brightness.

Over a wide range of samples, an increase of diffusion reduces the straight-through brightness factor but makes little difference at 25° or 30°. This effect gives control over hot-spot.

A number of typical brightness vs.

angle curves are presented in the paper. A study of the results shows that the following factors do not affect the optical properties of the screen:

1. It does not matter whether the diffusing particles are on or near the surface or are embedded throughout the base.

2. It makes no difference whether the diffusing material is incorporated in the liquid base plastic and cast, or whether the screen is built up by spraying a mixture of diffusing material and plastic lacquer.

3. The same diffusion is obtained by one high-diffusion screen or two low-diffusion screens placed close together. The latter, of course, may affect resolution in certain cases.

4. Over a considerable range, the size of the diffusing particles makes no difference. It is probable that the optical characteristics are chiefly controlled by the number of particles rather than the total weight. The largest particles should be considerably smaller than the screen thickness and the smallest should be several times the wavelength of light.

5. It is immaterial whether the diffusing particles are of uniform size or mixed.

The most important fact revealed by the investigation is that the shape of the polar diagram may be altered by changing the refractive index of the material used for the diffusing particles, so that by the correct choice the corner brightness is made as high as possible. Almost certainly the important criterion is the difference between the refractive indexes of the plastic base and the diffusing particles, but the indexes for all suitable plastics are similar so that the index for the particles is the most relevant. Experimentally, the preferred index is about 1.6 to 1.7, although no theoretical explanation has yet been established as to why this is the case.

III. Method of Manufacture of Screens

The use of powdered glass for high-diffusion screens is covered by British Patent 27,812 (1949). Essentially a method of making the screens consists of spraying a cellulose lacquer onto a false ceiling, powdered glass being mixed with the lacquer for some of the layers.

The ceiling used is constructed of ordinary trowelled plaster on the usual laths, supported from a suitable framework. The spraying is done from below. The plaster is first prepared by spraying it with a suitable gelatin solution. It is followed by applying a layer of ethyl cellulose lacquer with a spray gun. Fabric tapes are then applied to strengthen the edges of the screen. The powdered glass is next sprayed on, this being the most difficult part of the process since uniformity of coverage must be achieved. The powdered glass is mixed into the lacquer for spraying, a true wet spray being obtained. After drying two or three days, the screen is stripped off the gelatin-treated plaster. Eyelets are put into the edge-tapes, and after the screen has been laced into a frame it is ready for use.

The Scientific Basis for Establishing Brightness of Motion Picture Screens

A Discussion of Screen Brightness

By Frederick J. Kolb, Jr.

Discussion Participants

W. W. Lozier, Chairman of the Screen Brightness Committee, National Carbon Co. Division of U. C. & C. Corp.
G. A. Chambers, Eastman Kodak Co. Motion Picture Film Dept.
R. M. Evans, Eastman Kodak Co. Color Control Dept.
F. J. Kolb, Jr., Eastman Kodak Co. Dept. of Manufacturing Experiments
D. F. Lyman, Eastman Kodak Co. Camera Works
S. M. Newhall, Eastman Kodak Co. Color Control Dept.
Brian O'Brien, University of Rochester Institute of Optics
Otto Sandvik, Eastman Kodak Co. Research Laboratory
S. D. S. Spragg, University of Rochester Dept. of Psychology
K. F. Weaver, Eastman Kodak Co. Research Laboratory
D. Wood, Eastman Kodak Co. Camera Works

Last summer, Dr. Lozier, as Chairman of the Screen Brightness Committee, initiated a discussion of the scientific basis for establishing screen-brightness values, in order to secure technical advice for the Committee. Prof. O'Brien suggested that a conference be held at Rochester, N.Y., and as a matter of expediency only men available in Rochester were asked to attend. These were men actively engaged in the fields of projection optics and psychology. This report covers the discussion held at Rochester on June 19, 1950.

Purpose of the Discussion

Dr. Lozier reviewed the background for this discussion by noting that a "temporary standard" for the brightness of motion picture screens was adopted by the Society in 1938,[1] after the available data had been summarized in the 1935–36 symposium of the Screen Brightness Committee.[11] Slight modification was made in 1944,[2] but actually the interval from 1936 to the present has been characterized by the accumulation of considerable fundamental information without the opportunity for consolidating the data, or for the Screen Brightness Committee to consider modification of the temporary standard. This meeting of specialists active in fields relating to the screen brightness of projected pictures, therefore, was called to discuss the experimental and research accomplishments since 1936, to review and redefine the present gaps in our scientific background, and to discuss possible programs for collecting the information that should be available in order to reassess the screen-brightness standard.

INTRODUCTION

The present standard for screen brightness (Z22.39–1944),[2] Dr. Lozier pointed out, specifies "the brightness at the center of a screen for viewing 35-mm motion pictures shall be 10 ft-L (+4 or −1 ft-L) when the projector is running with no film in the gate."

Origin of Standard

In discussing the present standard, Dr. Lozier pointed out the work culminating in the SMPE symposium of 1935–36 which led to the adoption of a screen brightness standard. The Committee report,[11] relying upon the survey of technical knowledge presented in the symposium, discussed, first, the desirable levels of screen illumination, and second, attainable levels. The fundamental data of physiological optics were not directly applicable to the problem at that time, the Committee concluded, because the work had not been complete enough to permit the prediction of response under theater viewing conditions. Instead, consideration was given to the more practical experiments reported by Luckiesh and Moss,[7] Wolfe,[15] and O'Brien and Tuttle.[8] From these observations the Committee concluded that an ideal brightness level probably should be something in the order of 30-ft L, and that a peripheral brightness of the order of 0.05 ft-L would be desirable at this brightness level.

Considering next the properties of release prints, the Committee decided, on the basis of the work reported by Tuttle[14] that very little change in print density can be expected since: (1) Release prints can be made no more transparent because of the limitations of the existing photographic materials; lighter printing would endanger tone reproduction in the highlights. (2) It would not be practical to increase print density since an increase of about 0.15 in density would be necessary to place the highlight density of release prints nearer to the straight-line portion of the characteristic curve for positive film; one might thereby improve tone reproduction, but only at the expense of a necessary increase in illumination approximating 40% to maintain equal apparent brightness. For the slight advantage offered, this shift in print density (probably requiring a reduction in screen size to maintain picture brightness) was judged impractical.

Considering then what screen brightnesses might be possible with existing equipment, the Committee concluded that for a 30-ft screen an attainable brightness of about 7 ft-L would be the maximum. In order to reduce the discrepancy among theaters, and between theaters and review rooms, the Committee decided that a temporary standard on the basis of attainable brightness would have the advantage of stimulating an over-all improvement in picture quality. Therefore, assuming that a 30-ft screen might be the maximum size which the Society should attempt to recognize, the Committee decided that the minimum acceptable screen brightness should be 7 ft-L. In order to choose an upper limit the Committee attempted to determine what range of brightness could be tolerated without an objectionable change in the apparent contrast of the picture. It was considered undesirable to set the upper limit at 30 ft-L, since this would result in an excessive spread in screen brightnesses among the various theaters. On the basis of Blanchard's data[3] relating the Fechner fraction to field brightness, the Committee selected a maximum value of screen brightness such that the predicted apparent change in contrast would be 15% between the average and either extreme (for picture densities corresponding either to the average of the whole frame, or to the area of principal interest).

Summarizing its recommendations, the Committee said, "The value 7 is

based upon the value attainable for a diffusing screen about 30 ft wide with an efficient optical system in good adjustment. The value 14 is the limiting value beyond which print contrast adjusted for the mean level of 10 ft-L will appear too great. The value should be determined at the center of the screen, with a projector running, with no film in the gate." Subsequently, the Screen Brightness Committee suggested a modification in this standard from 7–14 ft-L to 9–14 ft-L in 1941[12]; the revised standard was adopted by the ASA in 1944.[2]

It should be emphasized especially for those not used to motion picture practice that the screen brightness as specified by the standard is markedly reduced when there is film in the projector and a picture on the screen. Assuming Tuttle's data[14] to be approximately correct for the fine-grain print stock now generally used, *actual picture brightnesses* for a "screen brightness" of 10 ft-L would be as shown in Table I.

16-Mm Projection

The problems of screen brightness for both 35-mm and 16-mm are generally similar, and 16-mm practice has tended to follow the 35-mm standard. It is usual, however, to permit a higher variation from the average brightness in 16-mm installations.

Recent Work

Since the 1936 symposium there has been considerable discussion and some additional work pertinent to the setting of a suitable screen-brightness standard. Reeb[9] reported results of an experimental study in Germany, investigating the contrast sensitivity of the eye under conditions similar to those found in viewing motion pictures. The German investigators concluded that maximum contrast sensitivity occurs at about 14 ft-L, that only the central brightness is important in attaining visual effect, that rapid changes in brightness of a scene do not affect sensitivity, and that screen areas of varying sizes do not cause different brightness impressions. From this it was concluded that the optimum brightness level would be 14 ft-L with the improvement being gradual beyond 8 ft-L. The German investigators further proposed that standardization would be incomplete without specification of the permissible drop of brightness with angle of view, since directional screens are becoming important.

A British survey[4] examined visibility of grain, appearance of flicker and glare, and also tabulated specific comments on individual subjects and on the general quality of projection. From these data curves were prepared from which the Committee concluded that screen brightnesses should conform to the following:

Subject	*Min.*	*Max.*
Black-and-White..	12 ft-L	24 ft-L
Technicolor.......	7 ft-L	14 ft-L

Table I

	Print Density			Screen Brightness, ft-L		
	Min.	Mean	Max.	Max.	Mean	Min.
Average of entire frame...............	0.67	1.15	1.90	2.1	0.71	0.13
"Face" or area of principal interest.....	0.60	0.99	1.60	2.5	1.0	0.25
Brightest highlight..................	0.19	0.43	0.90	6.5	3.7	1.3
Deepest shadow.....................	1.87	2.40	3.20	0.13	0.040	0.0063
Highest scene contrast = 2.45				Lowest scene contrast = 1.38		

As a summary recommendation, the Committee proposed a minimum screen brightness of 8 ft-L and a maximum of 16 ft-L, and this has been adopted as British Standard 1404.[4]

Further discussions[5,6,10,13] have been published but it does not seem that they offer any additional basic data suitable for the further analysis of this particular problem. In many cases, however, they provide excellent summaries of the data available and of the practical application of the data, and of standards and recommendations.

Temporary Nature of Standard

In the report of the Projection Screen Brightness Committee presented at the 1936 Spring Meeting it was emphasized that their recommendation was for a tentative standard, to be modified as soon as practical: "It appears to the Committee in view of the arguments that have been presented, that the industry might stand to benefit by the adoption of a temporary screen-brightness standard. Logical limits for such a standard would appear to be 7 ft-L for the low value and 14 for the high value." In its discussion, the Committee concluded that on the other hand an ideal standard "should be something of the order of 30 ft-L and that a peripheral brightness of the order of 0.05 ft-L is desirable at this brightness level. If such a brightness were obtainable logical brightness limits would be 20 ft-L minimum and 45 ft-L maximal."

Having thus proposed a temporary standard—pending the accumulation of more satisfactory data, and pending improvements in the mechanics of projection that might permit higher brightnesses—the Committee listed some of the questions which should be answered in order that the temporary standard might be replaced by an operating standard closer to the ideal range of screen brightness. These questions promulgated in 1936 are as follows:

1. What correlation is there between best print contrast and screen brightness?

2. What effect does the brightness standard have upon the standard of release print quality? Shall release prints of different contrasts be made available to theaters operating at different screen-brightness levels? (Any work done on the standard release print must, for obvious reasons, consider the screen-brightness standard if it is adopted.)

3. Is highlight density, average density, shadow density, density of the area of principal interest, or a combination of these factors, the thing that determines preferred brightness?

4. What possibilities are there for improvement in projection optics, pull-down efficiency, and source brilliance?

5. What is the effect of color of the light source, color of the screen, and color of the print upon the desired brightness?

6. What proportion of moving picture goers see pictures on screen greater than 20 ft, 25 ft, 30 ft? Statistical data on theater sizes, screen sizes, projection equipment and attendance figures are needed by the Committee. A complete paper of this kind would be valuable also in connection with other problems confronting the Society.

7. What factors determine screen width? Would it not be better, for instance, to use a 25-ft screen at 9 ft-L than a 30-ft screen at 7 ft-L? The data of visual acuity tell us that the picture detail visible at great viewing distances should not suffer.

8. What are the possibilities for the development of simple, rugged, and inexpensive brightness-measuring instruments? Cannot a satisfactory simple brightness tester be developed with two fields, one at the higher and one at the lower brightness limit? Could not such an instrument be used easily by the theater projectionist to determine whether he is operating within the recommended brightness range?

9. What is the effect of auditorium illumination upon the required brightness level?

10. What is the effect of the visual angle or the screen size upon this value?

11. What tolerance in nonuniformity of screen brightness from center to edge should be established?

RECENT WORK ON SCREEN BRIGHTNESS

In order to provide a basis for reappraisal of the screen-brightness problem, Dr. Lozier, as Chairman of the Committee, had initiated the conference on June 19, 1950, to discuss what new knowledge was available for supplementing the 1936 summary.

None at the discussion could recall that any work specifically pertinent to the determination of a standard of screen brightness or to the conditions of theater viewing had been accomplished in the interval since 1936. Prof. O'Brien reported that the visual work since that time has been so fundamental in nature or directed to such different ends that its interpretation for the setting of theater viewing conditions might be extremely difficult. The conference thought that the list of questions proposed by the Committee in 1936 was as adequate now as it had been at that time, that little progress has been made toward a direct answer to any of the questions, and that any such answer would result only from studies purposely designed to investigate the desirable brightness of projected pictures.

It was the consensus of the conference that a great deal of work could be done toward determining optimum conditions of theater viewing and that it would be worth while for the Screen Brightness Committee to sponsor such a research program. It was also felt that it should not be too difficult to outline experiments and to formulate a program which would take sufficient account of the difficulties involved to make a real contribution, and to be free of many of the criticisms leveled at early work on screen brightness.

Conditions of Experimentation

The conference agreed that any work pertinent to the determination of optimum theater viewing conditions must simulate very closely the actual theater viewing. Prof. O'Brien and Mr. Evans warned particularly against inferring from the measurement of fundamental visual functions the result under theater viewing conditions. The knowledge of vision and the contribution of the visual functions to the total task of viewing are insufficiently understood.

Scope of Research

In suggesting and sponsoring research on theater viewing the Screen Brightness Committee will be asked to indicate what scope of variables should be included. In the conference discussion, it seemed obvious that the viewing conditions must include the full range of present indoor and outdoor theaters when projecting motion pictures. It is probable that it should include also the range of projected theater television.

Furthermore, research sponsored by the Screen Brightness Committee should aim to determine optimum viewing conditions regardless of their practicability. The research moreover should determine what compromises with this optimum can be made with the least sacrifice of picture quality. The program should thus serve to indicate the goal toward which development of motion picture projection should proceed and should also indicate what temporary compromises with that objective can be made most justifiably.

Mr. Evans noted the corollary position of the various television committees which have been searching for data in this same field. If their research covered all television viewing while the Screen Brightness Committee considered motion picture viewing, the data for the two fields would be complementary. For example, theater viewing probably covers the range of viewing distances from 1½ to 6 screen widths while television viewing begins at 6–7 screen widths and continues to greater distances.

DISCUSSION OF SIGNIFICANT VARIABLES

Most important to the outlining of a proper research program the discussion felt was a tabulation of significant variables in theater viewing so that proper account could be taken in setting up experiments. The conference enumerated the following variables as definitely significant: (1) screen brightness; (2) surround brightness; (3) conditioning level of illumination; (4) viewing angle; (5) viewing distance; and (6) subject matter of test pictures.

A primary contribution of the meeting was a discussion of these variables; the discussion has been taken out of its temporal sequence and here organized by subject.

1. Screen Brightness

Sensitivity of the observer to brightness changes was discussed, with Dr. Lozier and Mr. Chambers feeling that equal percentage changes in illumination are more visible at the lower brightness levels; for example at 2 ft-L a 100% increase in brightness appears more effective than a 100% increase at a level of 15 ft-L. Dr. Newhall suggested that the magnitude of such perception of brightness change is influenced greatly by the conditioning level of illumination preceding the test.

Color of the illuminant used during the test is important; Mr. Chambers reported that the optimum level chosen under incandescent illumination has been found to be different from that chosen under arc illumination and that in particular the apparent contrast of a picture appears higher with arc quality illumination. Mr. Evans agreed that the apparent contrast of the image varies considerably with the color of the illuminant.

Flicker inherent in the intermittent projection of motion pictures was discussed from two viewpoints: (1) the proper integration of an intermittently illuminated image, and (2) the perception of flicker as a distracting influence. The discussers felt that the indications of meters and measuring devices used to correlate work on screen brightness must be such as to have a response to intermittent illumination consistent with the response of the human eye. With reference to the level at which flicker becomes distracting, Dr. Lozier reported observations indicating that flicker is objectionable above 15–20 ft-L. Prof. O'Brien on the other hand found no objectionable flicker in his experiment[8] at levels up to 30 ft-L. Mr. Evans noted that while the threshold for foveal flicker is not exceeded by 48-cycle illumination at 30 ft-L, on the other hand the threshold for peripheral flicker at that intensity is well above 48 cycles. Peripheral flicker begins to be observed at 48 cycles in the range of 15 ft-L. Thus, the sensitivity to flicker and the effect of flicker as a disturbing influence will be a function of viewing angle, decreasing as the viewing angle is decreased and as the vision becomes more nearly limited to the foveal region.

2. Surround Brightness

Prof. O'Brien reported that in his opinion if his earlier research had made any single contribution it was to indicate that some definite surround brightness is desirable in the viewing of motion pictures, and that under normal theater conditions a surround brightness of approximately 0.05 ft-L is preferred by observers free to choose. Dr. Spragg reported that wartime research on radar-screen viewing showed significantly better performance of the observer with a definite surround brightness. There was less fatigue, better perception of detail, and quicker response to the image, as the surround brightness was progressively increased up to levels nearly equal to the screen brightness itself.

Mr. Evans pointed out that—entirely apart from the fatigue, ease, and pleasure of viewing—the surround-brightness

level changes the appearance of the picture; as the surround brightness is increased from zero up to the highlight brightness the illusion changes from that of viewing a projected picture to that of viewing a print.

Consequently, one factor influencing surround brightness is the determination of which viewing effect is desired and what criterion of desirability is chosen. Some of the newest theaters Evans noted are being so built as to use a graded surround illumination. Dr. Newhall pointed out that the "surround effect" depends very much upon the visual angle subtended by the screen and also upon the portion of the total visible angle that is covered by the "surround" under consideration.

3. *Conditioning Level of Illumination*

Dr. Newhall pointed out several times during the discussion that the results obtained in a study of vision such as is anticipated in this discussion, depend greatly upon the conditioning level of illumination. He stressed the importance of conducting the test with the observers conditioned in the manner of a practical theatre audience.

4. *Viewing Angle*

Dr. O'Brien in summarizing his previous experiments felt the outstanding defect was too restricted a viewing angle and pointed out that this defect was common to most of the early work on theater viewing. Dr. Spragg and Dr. Newhall in discussing the interrelationship between surround brightness and viewing angle pointed out the possibility that the optimum brightness may be a function of the viewing angle and that it should be so specified. Such a relationship might provide a basis for correlating indoor and outdoor theater recommendations.

Mr. Evans pointed out that committees of the television industry have been formulating questions similar to those proposed by the Screen Brightness Committee of the SMPTE, and that the scientific information desired by each group has much in common. For example, television viewing is very similar to motion picture screen viewing excepting that motion picture screen viewing angles are from $1\frac{1}{2}$ to perhaps 6 screen widths while television viewing begins at 6 screen diameters and continues to smaller angles. Dr. O'Brien suggested a cooperative research effort to determine the functions of television and motion picture viewing, spanning this angular range.

5. *Viewing Distance*

Mr. Evans suggested that the influence of viewing distance cannot be neglected even when viewing angles are duplicated, and he recommended that at least some of the experimental work be done under the actual viewing distances—in addition to small screen studies that duplicate viewing angles only. One effect of viewing distance, for example, may be to influence the comfort of the visual task.

6. *Subject Matter of Pictures*

Mr. Evans pointed out that it may be much more important to have a large number of test scenes rather than to have a large number of viewers. He pointed out, for example, that the British choice[4] of 7 ft-L for Technicolor and 12 ft-L for black-and-white viewing can easily result from a difference in the subject matter of the two film sections, rather than any fundamental difference in viewing. Mr. Evans and Dr. O'Brien proposed that by all means both color and black-and-white films be used.

There was at first a proposal that the viewing should duplicate actual conditions, employing a sound track along with the picture since that is the normal projection procedure. Mr. Evans and Mr. Weaver objected, however, pointing out that if sound affects vision, it will not be nearly so easy to judge how

pleasing the picture is if there is a simultaneous, possibly distracting, sound track. If other than the viewing task itself is examined, Dr. O'Brien pointed out, there will be no way of judging picture quality except by apparent fatigue, headache, etc. (Actually there seems to be no such thing as strictly visual fatigue, Dr. O'Brien pointed out, since the factors formerly attributed to "visual fatigue" are being explained by other factors entirely.)

Dr. O'Brien reported that the pictures for his experiment[8] were chosen purposely to have neither interest nor boredom, because it was necessary to project them a number of times in testing a single observer. The results in such a test, he pointed out, may be different from those that would be secured with an interesting picture viewed for the first time only. Dr. Newhall emphasized that pertinent research must be based upon typical films.

In the discussion of color versus black-and-white, Dr. Spragg asked whether the permissible brightness range might be more closely limited for color pictures. Mr. Evans pointed out that color prints cannot be projected with as high screen brightnesses as black-and-white prints without a shift in color balance. Most color processes tend to depart from balance in the deep shadows and the brightnesses must be kept low enough so that this departure is not obvious. The lower screen-brightness limits for acceptable image quality of both black-and-white and color appear to be equal.

The print density should correlate with release prints; Mr. Chambers pointed out that Mr. Tuttle's[14] early work on print density is no longer applicable because of the general change to fine-grain emulsions for black-and-white, and that therefore the measurements of current print densities should be repeated. The question was raised and left unanswered—whether the ultimate result of increased available screen brightness might not be a mere increase in print density. Mr. Chambers pointed out the commercial necessity for screen brightness uniformity such that the review-room brightnesses match the theater brightnesses, in order for the exhibitors to realize the kind of picture that is created by the directors and producers. Failure to keep this balance is responsible for the poor reception of some otherwise good pictures.

Nature of the Observer's Report

Dr. Spragg suggested that since the purpose of these experiments is to provide better theater viewing, the most important criterion is to meet the observer's preference. This type of judging was the basis of Dr. O'Brien's early experiments. Dr. Spragg suggested getting data from large-scale experiments such as a whole auditorium full of observers.

It is desirable, the group agreed, to get observers who are not self-conscious of their task. This is difficult to realize, however, and the use of repeated matter with fewer observers is an experimental risk that sometimes cannot be avoided.

Dr. Spragg suggested that in his experience it has been preferable to have untrained observers judge which of several conditions they prefer rather than to have them manipulate conditions to reach an optimum. Typical of this procedure, Dr. Spragg pointed out, is the CBS practice of equipping its studio audiences with "yes" or "no" push buttons which are summed electrically. The audience is asked to indicate its reaction to the show as it progresses, and the electrical summation gives a continuous record of show interest.

Mr. Weaver proposed audience sampling, giving cards to the patrons of actual theaters, on which they might indicate how they liked the performance and whether they would prefer to have had a brighter or dimmer picture. Such sampling can be done at successive

shows at varying screen brightnesses.

Mr. Chambers suggested that audience background-noise level might be lower and applause- and laughter-level higher at the best projection brightness levels, therefore, a better method of audience sampling might be to record the audience-noise level—"applause meter reading"—in a theater where the screen brightness can be varied from one day to another. This recording meter program, he pointed out, is extensively used in Hollywood to judge previews, and there has been found a presumable relationship between audience enjoyment and audience-noise level. Dr. Spragg observed that the audience reaction to the pictures as judged by such meters is consistent and if an audience laughs for a given time at a particular part of the picture each audience will repeat with amazing reproducibility. Mr. Chambers pointed out that Mr. Sponable's group at 20th Century-Fox has used such meters in their West Coast preview theaters and that equipmentwise they are prepared to provide a range of screen brightnesses up to and beyond the usual levels. He suggested that 20th Century-Fox be invited to run such tests in their West Coast theaters now fitted with these applause meters, where on successive days of projecting the same program, the screen brightness would be varied and the day-to-day audience reaction compared. Such a comparison, Mr. Chambers pointed out, might give some very real and important data for answering the question of whether screen brightness is really important in judging the quality of a projected picture.

PROPOSED ACCOMPLISHMENTS

In the discussion it was pointed out that the present standard, while intended to be temporary, has functioned as a permanent standard for 15 years. During this time changes in equipment, films, theaters, etc. have been directed by the existence of this standard toward the maintenance of a constant screen brightness with variations in picture size, etc. It would be desirable, therefore, for fundamental research to indicate more clearly what optimum screen brightnesses should be, so that future technical improvements could be directed toward this optimum.

Even though present limitations might make it impossible for the optimum brightness to be realized and even though a working standard might have to compromise with this optimum, the existence of suitable basic data should make possible the best possible compromise. Accordingly the best attainable projection conditions would become the working standard, with future technical advances directed closer and closer to the optimum.

CONCLUSIONS

Consensus of opinion of this discussion was that a great deal of basic data on the factors influencing the viewing of projected pictures still remains to be determined. The conference agreed that it should be entirely practical for the Screen Brightness Committee to outline desirable research goals in such a manner that intelligent work directed toward their end would provide a real contribution to the science of viewing. Suitable explanatory matter, detailed outlines of procedures, and consultative guidance could be provided, the conference felt, to insure that such research programs may contribute basic knowledge and not unnecessarily further becloud the issue.

The conference felt that if the problems could be stated properly and succinctly, and if suitable guidance could be available, there might be a number of

groups willing to undertake the work as: (1) university research by students and staff members interested in the general field; or (2) industrial research sponsored by the companies interested in motion picture projection.

References

1. American Standard: "Projection Screen Brightness," Z22.41–1938 (SMPE Standard RPm-3-1).
2. American Standard: "Screen Brightness for 35-Millimeter Motion Pictures," Z22.39–1944.
3. J. Blanchard, "The Brightness Sensibility of the Retina," *Phys. Rev.*, vol. 11, no. 2, p. 81, Feb. 1918. Quoted *Jour. SMPE*, vol. 27, pp. 133 and 137, Aug. 1936.
4. British Standards Institute: "Screen Brightness for the Projection of 35-Mm Film." British Standard 1404.
5. W. Kalb, "Progress in Projection Lighting," *Jour. SMPE*, vol. 35, pp. 17–31, July 1940.
6. H. Logan, "Brightness and Illumination Requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.
7. M. Luckiesh and F. K. Moss, "The Motion Picture Screen as a Lighting Problem," *Jour. SMPE*, vol. 26, pp. 578–591, May 1936.
8. B. O'Brien and C. M. Tuttle, "An Experimental Investigation of Projection Screen Brightness," *Jour. SMPE*, vol. 26, pp. 505–521, May 1936.
9. O. Reeb, "A Consideration of the Screen Brightness Problem," *Jour. SMPE*, vol. 32, pp. 485–494, May 1939.
10. B. Schlanger, "Projectionist's Interest in Auditorium Viewing Conditions," *Jour. SMPE*, vol. 34, pp. 585–588, June 1940.
11. "SMPE Projection Screen Brightness Committee Report," *Jour. SMPE*, vol. 27, pp. 127–139, Aug. 1936.
12. "SMPE Standards Committee Report," *Jour. SMPE*, vol. 36, pp. 260–266, Mar. 1941. Includes SMPE Recommended Practice for 35-mm Film; "Projection Screen Brightness" Jan. 1941.
13. SMPTE Screen Brightness Committee: "A Bibliography on Preferred Levels of Motion Picture Screen Illumination" prepared by M. S. Wright, National Carbon Research Library, April 4, 1950 (available from the SMPTE).
14. C. M. Tuttle, "Density Measurements of Release Prints," *Jour. SMPE*, vol. 26, pp. 548–553, May 1936.
15. S. K. Wolf, "An Analysis of Theater and Screen Illumination Data," *Jour. SMPE*, vol. 26, pp. 532–547, May 1936.

Constitution of the Society of Motion Picture and Television Engineers

ARTICLE I

NAME

The name of this association shall be SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS.

ARTICLE II

OBJECTS

Its objects shall be: Advancement in the theory and practice of engineering in motion pictures, television, and the allied arts and sciences; the standardization of equipment and practices employed therein; the maintenance of a high professional standing among its members; and the dissemination of scientific knowledge by publication.

ARTICLE III

MEETINGS

There shall be an annual meeting and such other regular and special meetings as provided in the Bylaws.

ARTICLE IV

ELIGIBILITY FOR MEMBERSHIP

Any person of good character is eligible to become a member in any grade for which he is qualified in accordance with the Bylaws.

ARTICLE V

OFFICERS

The officers of the Society shall be a President, an Executive Vice-President, a Past-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of all elected officers shall be for a period of two years.

The President shall not be eligible to succeed himself in office.

At the conclusion of his term of office the President automatically becomes Past-President.

Under conditions as set forth in the Bylaws, the office of Executive Vice-President may be vacated before the expiration of his term.

A vacancy in any office shall be filled for the unexpired portion of the term in accordance with the Bylaws.

ARTICLE VI

SECTIONS

Sections may be established in accordance with the Bylaws.

ARTICLE VII

BOARD OF GOVERNORS

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and twelve elected Governors. An equal number of these elected Governors shall reside within the areas included in the Eastern time zone; the Central time zone; and the Pacific and Mountain time zones. The term of office of all elected Governors shall be for a period of two years.

ARTICLE VIII

AMENDMENTS

This Constitution may be amended as follows: Amendments may originate as recommendations within the Board of Governors, or as a proposal to the Board of Governors, by any ten members of voting grade; when approved by the Board of Governors as set forth in the Bylaws, the proposed amendment shall then be submitted for discussion at the annual meeting or at a regular or special meeting called as provided in the Bylaws. The proposed amendment, together with the discussion thereon, shall then be promptly submitted by mail to all members qualified to vote, as set forth in the Bylaws. Voting shall be by letter ballot mailed with the proposed amendment and discussion to the voting membership. In order to be counted, returned ballots must be received within sixty (60) days of the mailing-out date. An affirmative vote of two thirds of the valid ballots returned, subject to the above time limitations, shall be required to carry the amendment, provided one fifteenth of the duly qualified members shall have voted within the time limit specified herein.

BYLAWS OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

BYLAW I

MEMBERSHIP

Sec. 1. Membership of the Society shall consist of the following grades: Honorary members, Sustaining members, Fellows, Active members, Associate members and Student members.

An *Honorary member* is one who has performed eminent service in the advancement of engineering in motion pictures, television, or allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A *Sustaining member* is an individual, company, or corporation subscribing substantially to the financial support of the Society.

A *Fellow* is one who shall be not less than thirty years of age and who shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture or television industries. A Fellow shall be entitled to vote and to hold any office in the Society.

An *Active member* is one who shall be not less than twenty-five years of age and shall be or shall have been either one or an equivalent combination of the following:

(a) An engineer or scientist in motion picture, television or allied arts. As such he shall have performed and taken responsibility for important engineering or scientific work in these arts and shall have been in the active practice of his profession for at least three years, or

(b) A teacher of motion picture, television or allied subjects for at least six years in a school of recognized standing in which he shall have been conducting a major course in at least one of such fields, or

(c) A person who by invention or by contribution to the advancement of engineering or science in motion picture, television or allied arts, or to the technical literature thereof, has attained a standing equivalent to that required for Active membership in (a), or

(d) An executive who for at least three years has had under his direction important engineering or responsible work in the motion picture, television or allied industries and who is qualified for direct supervision of the technical or scientific features of such activities. An Active member shall be entitled to vote and to hold any office in the Society.

An *Associate member* is one who shall be not less than eighteen years of age, and shall be a person who is interested in the study of motion picture or television technical problems or connected with the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges on action taken by the committee.

A *Student member* is any person registered as a student, graduate or undergraduate, in a college, university, or other educational institution of like scholastic standing, who evidences interest in motion picture or television technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A student member shall have the same privileges as an Associate member of the Society.

Sec. 2. All applications for membership or transfer should be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow grades may not be applied for.

Sec. 3. (a) Honorary membership may be granted upon recommendation of the Honorary Membership Committee when confirmed first by a three-fourths majority vote of those present at a meeting of the Board of Governors, and then by a four-fifths majority vote of all voting members present at any regular meeting or at a special meeting called as stated in the bylaws. An Honorary member shall be exempt from the payment of all dues.

(b) Upon recommendation of the Fellow Award Committee, when confirmed by a three-fourths majority vote by those present at a meeting of the Board of Governors, an Active member may be made a Fellow.

(c) An Applicant for Active membership shall give as references at least two mem-

bers of the grade applied for or of a higher grade. Applicants shall be elected to membership by a three-fourths majority vote of the entire membership of the appropriate Admissions Committee. An applicant may appeal to the Board of Governors if not satisfied with the action of the Admissions Committee, in which case approval of at least three-fourths of those present at a meeting of the Board of Governors shall be required for election to membership or to change the action taken by the Admissions Committee.

(d) An applicant for Associate membership shall give as reference one member of the Society, or two persons not members of the Society who are associated with the motion picture, television, or allied industry. Applicants shall be elected to membership by approval of the Chairman of the appropriate Admissions Committee.

(e) An applicant for Student membership shall be sponsored by a member of the Society, or by a member of the staff of the department of the institution he is attending, this faculty member not necessarily being a member of the Society. Applicants shall be elected to membership by approval of the Chairman of the appropriate admissions committee.

Sec. 4. Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors, provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

BYLAW II

OFFICERS

Sec. 1. An officer or governor shall be an Honorary member, Fellow, or an Active member.

BYLAW III

BOARD OF GOVERNORS

Sec. 1. The Board of Governors shall transact the business of the Society in accordance with the Constitution and Bylaws.

Sec. 2. The Board of Governors may act on special resolutions between meetings, by letter ballot authorized by the President. An affirmative vote from a majority of the total membership of the Board of Governors shall be required for approval of such resolutions.

Sec. 3. A quorum of ten members of the Board of Governors shall be present to vote on resolutions presented at any meeting. Unless otherwise specified, a majority vote of the Governors present shall constitute approval of a resolution.

Sec. 4. A member of the Board of Governors may not authorize an alternate to act or vote in his stead.

Sec. 5. Vacancies in the offices or on the Board of Governors shall be filled by the Board of Governors until the annual elections of the Society.

Sec. 6. The Board of Governors, when filling vacancies in the offices or on the Board of Governors, shall endeavor to appoint persons who in the aggregate are representative of the various branches or organizations of the industries interested in the activities of the Society to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of such industries.

Sec. 7. The time and place of all except special meetings of the Board of Governors shall be determined by the Board of Governors.

Sec. 8. Special Meetings of the Board of Governors shall be called by the President with the proviso that no meeting shall be called without at least seven days prior notice to all members of the Board by letter or telegram. Such a notice shall state the purpose of the meeting.

BYLAW IV

ADMINISTRATIVE PRACTICES

Sec. 1. Special rules relating to the administration of the Society and known as Administrative Practices shall be established by the Board of Governors and shall be added to or revised as necessary to the efficient pursuit of the Society's objectives.

BYLAW V

COMMITTEES

Sec. 1. All committees, except as otherwise specified, shall be formed and appointed in accordance with the Administrative Practices as determined by the Board of Governors.

Sec. 2. All committees, except as otherwise specified, shall be appointed to act for the term served by the officer charged with appointing the committees or until he terminates the appointment.

Sec. 3. Chairmen of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4. Standing Committees of the Society to be appointed by the President and confirmed by the Board of Governors are as follows:

Honorary Membership Committee
Journal Award Committee
Nominating Committee
Progress Medal Award Committee
Public Relations Committee
Samuel L. Warner Memorial Award Committee

Sec. 5. There shall be an Admissions Committee for each Section of the Society composed of a chairman and three members of which at least two shall be members of the Board of Governors.

Sec. 6. There shall be a Fellow Award Committee composed of all the officers and section chairmen of the Society under the chairmanship of the Past-President. In case the chairmanship is vacated it shall be temporarily filled by appointment by the President.

BYLAW VI

MEETINGS OF THE SOCIETY

Sec. 1. The location and time of each meeting or convention of the Society shall be determined by the Board of Governors.

Sec. 2. The grades of membership entitled to vote are defined in Bylaw I.

Sec. 3. A quorum of the Society shall consist in number of $\frac{1}{15}$ of the total of those qualified to vote as listed in the Society's records at the close of the last fiscal year before the meeting.

Sec. 4. The annual meeting shall be held during the fall convention.

Sec. 5. Special meetings may be called by the President and upon the request of any three members of the Board of Governors not including the President.

Sec. 6. All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

BYLAW VII

DUTIES OF OFFICERS

Sec. 1. The President shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2. In the absence of the President, the officer next in order as listed in Article V of the Constitution shall preside at meetings and perform the duties of the President.

Sec. 3. The seven officers shall perform the duties separately enumerated below and those defined by the President:

(a) The Executive Vice-President shall represent the President, and shall be responsible for the supervision of the general affairs of the Society as directed by the President.

The President and the Executive Vice-President shall not both reside in the geographical area of the same Society Section, but one of these officers shall reside in the vicinity of the executive offices. Should the President or Executive Vice-President remove his residence to the same geographical area of the United States as the other, the office of Executive Vice-President shall immediately become vacant and a new Executive Vice-President shall be elected by the Board of Governors for the unexpired portion of the term.

(b) The Engineering Vice-President shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and co-ordination of the work of these committees.

(c) The Editorial Vice-President shall be responsible for the publication of the Society's *Journal* and all other Society publications.

(d) The Financial Vice-President shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets prepared by him and approved by the Board of Governors.

(e) The Convention Vice-President shall be responsible for the national conventions of the Society. He shall arrange for at least one annual convention to be held in the fall of the year.

Sec. 4. The Secretary shall keep a record of all meetings; and shall have the responsibility for the care and custody of records, and the seal of the Society.

Sec. 5. The Treasurer shall have charge of the funds of the Society and disburse them as and when authorized by the Financial Vice-President. He shall be bonded in an amount to be determined by the Board of Governors, and his bond shall be filed with the Secretary.

Sec. 6. Each officer of the Society, upon the expiration of his term of office, shall

transmit to his successor a memorandum outlining the duties and policies of his office.

BYLAW VIII

SOCIETY ELECTIONS

Sec. 1. All officers and governors shall be elected to their respective offices by a majority of ballots cast by voting members in the following manner:

Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a Chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other voting members, not currently officers or governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee.

Not less than three months prior to the Annual Fall Meeting, the Board of Governors shall review the recommendations of the Nominating Committee, which shall have nominated suitable candidates for each vacancy.

Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting. The Secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Governors may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the Secretary's address and a space for the member's name and address. One set of these shall be mailed to each voting member of the Society, not less than forty days in advance of the annual fall meeting.

The voter shall then indicate on the ballot one choice for each vacancy, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelope shall be delivered by the Secretary to a Committee of Tellers appointed by the President at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and governors of the Society shall take office on January 1, following their election.

BYLAW IX

DUES AND INDEBTEDNESS

Sec. 1. The annual dues shall be fifteen dollars ($15) for Fellows and Active members, ten dollars ($10) for Associate members, and five dollars ($5) for Student members, payable on or before January 1, of each year. Current or first year's dues for new members in any calendar year shall be at the full annual rate for those notified of election to membership on or before June 30; one half the annual rate for those notified of election to membership in the Society on or after July 1.

Sec. 2. (a) Transfer of membership to a higher grade may be made at any time subject to the requirements for initial membership in the higher grade. If the transfer is made on or before June 30, the annual dues of the higher grade are required. If the transfer is made on or after July 1, and the member's dues for the full year have been paid, one half of the annual dues of the higher grade is payable less one half the annual dues of the lower grade.

(b) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1, of each year.

Sec. 3. Annual dues shall be paid in advance.

Sec. 4. Failure to pay dues may be considered just cause for suspension.

BYLAW X

PUBLICATIONS

Sec. 1. The Society shall publish a technical magazine to consist of twelve monthly issues, in two volumes per year. The editorial policy of the *Journal* shall be based upon the provisions of the Constitution and a copy of each issue shall be supplied to each member in good standing mailed to his last address of record.

Copies may be made available for sale at a price approved by the Board of Governors.

BYLAW XI

LOCAL SECTIONS

Sec. 1. Sections of the Society may be authorized in any locality where the voting membership exceeds twenty. The geographic boundaries of each Section shall be determined by the Board of Governors. Upon written petition for the authorization of a Section of the Society, signed by twenty or more voting members, the Board of Governors may grant such authorization.

SECTION MEMBERSHIP

Sec. 2. All members of the Society of the Motion Picture and Television Engineers in good standing residing within the geographic boundaries of any local Section shall be considered members of that Section.

Sec. 3. Should the enrolled voting membership of a Section fall below twenty, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining that Section, the Board of Governors may cancel its authorization.

SECTION OFFICERS

Sec. 4. The officers of each Section shall be a Chairman and a Secretary-Treasurer. The Section chairmen shall be ex-officio members of the Board of Governors and shall continue in such positions for the duration of their terms as chairmen of the local Sections. Each Section officer shall hold office for one year, or until his successor is chosen.

SECTION BOARD OF MANAGERS

Sec. 5. The Board of Managers shall consist of the Section Chairman, the Section Past-Chairman, the Section Secretary-Treasurer, and six voting members. Each manager of a Section shall hold office for two years. Vacancies shall be filled by appointment by the Board of Managers until the annual election of the Section.

SECTION ELECTIONS

Sec. 6. The officers and managers of a Section shall be voting members of the Society. All officers and managers shall be elected to their respective offices by a majority of ballots cast by the voting members residing in the geographical area of the Section. Not less than three months prior to the annual fall convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the Chairman of the Section, consisting of seven members, including a chairman. The committee shall be composed of the present Chairman, the Past-Chairman, two other members of the Board of Managers not up for election, and three other voting members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify the candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Managers may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each voting member of the Society residing in the geographical area covered by the Section, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention. The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a

duly called meeting. The Board of Managers shall then examine the returned envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and managers shall take office on January 1, following their election.

SECTION BUSINESS

Sec. 7. The business of a Section shall be conducted by the Board of Managers.

SECTION EXPENSES

Sec. 8. (a) At the beginning of each fiscal year, the Secretary-Treasurer of each section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(b) The Treasurer of the Society shall deposit with each Section Secretary-Treasurer a sum of money for current expenses, the amount to be fixed by the Board of Governors.

(c) The Secretary-Treasurer of each Section shall send to the Treasurer of the Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding period.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) The Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally.

(f) The Secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

SECTION MEETINGS

Sec. 9. The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate. The Secretary-Treasurer of each Section shall forward to the Secretary of the Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

CONSTITUTION AND BYLAWS

Sec. 10. Sections shall abide by the Constitution and Bylaws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

BYLAW XII

STUDENT CHAPTERS

Sec. 1. Student Chapters of the Society may be authorized in any college, university, or technical institute of collegiate standing. Upon written petition for the authorization of a Student Chapter, signed by twelve or more Society members, or applicants for Society membership, and the Faculty Adviser, the Board of Governors may grant such authorization.

CHAPTER MEMBERSHIP

Sec. 2. All members of the Society in good standing who are attending the designated educational institution shall be eligible for membership in the Student Chapter, and when so enrolled they shall be entitled to all privileges that such Student Chapter may, under the Constitution and Bylaws, provide.

Sec. 3. Should the membership of the Student Chapter fall below ten, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

CHAPTER OFFICERS

Sec. 4. The officers of each Student Chapter shall be a Chairman and a Secretary-Treasurer. Each Chapter officer shall hold office for one year, or until his successor is chosen. Where possible, officers shall be chosen in May to take office at the beginning of the following school year. The procedure for holding elections shall be prescribed in Administrative Practices.

FACULTY ADVISER

Sec. 5. A member of the faculty of the same educational institution shall be designated by the Board of Governors as Faculty Adviser. It shall be his duty to advise the officers on the conduct of the Chapter and to approve all reports to the Secretary and the Treasurer of the Society.

CHAPTER EXPENSES

Sec. 6. The Treasurer of the Society shall deposit with each Chapter Secretary-Treasurer a sum of money, the amount to be fixed by the Board of Governors. The Secretary-Treasurer of the Chapter shall send to the Treasurer of the Society at the

end of each school year or on demand an itemized account of all expenditures incurred.

CHAPTER MEETINGS

Sec. 7. The Chapter shall hold at least four meetings per year. The Secretary-Treasurer shall forward to the Secretary of the Society at the end of each school year a report of the meetings for that year, giving the subject, speaker, and approximate attendance for each meeting.

BYLAW XIII

AMENDMENTS

Sec. 1. Proposed amendments to these Bylaws may be initiated by the Board of Governors or by a recommendation to the Board of Governors signed by ten voting members. Proposed amendments may be approved at any regular meeting of the Society at which a quorum is present, by the affirmative vote of two-thirds of the members present and eligible to vote thereon. Such proposed amendments shall have been published in the *Journal* of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

Sec. 2. In the event that no quorum of the voting members is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the Bylaws upon receiving the affirmative vote of three-quarters of the entire membership of the Board of Governors.

OFFICERS OF THE SOCIETY April, 1951

HERBERT BARNETT
Executive Vice-President
1951–52

PETER MOLE
President
1951–52

EARL I. SPONABLE
Past-President
1951–52

FRED T. BOWDITCH
Engineering Vice-President
1950–51

JOHN G. FRAYNE
Editorial Vice-President
1951–52

RALPH B. AUSTRIAN
Financial Vice-President
1950–51

WILLIAM C. KUNZMANN
Convention Vice-President
1951–52

ROBERT M. CORBIN
Secretary
1951–52

Frank E. Cahill, Jr.
Treasurer, 1950–51

Paul J. Larsen
Governor, 1950–51

Lorin D. Grignon
Governor, 1950–51

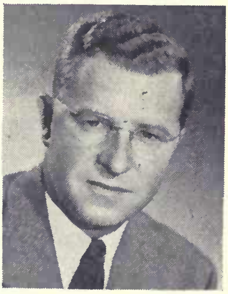
William H. Rivers
Governor, 1950–51

R. T. Van Niman
Governor, 1950–51

Edward S. Seeley
Governor, 1950–51

Frank E. Carlson
Governor, 1951–52

Thomas T. Moulton
Governor, 1951–52



William B. Lodge
Governor, 1951–52

Norwood L. Simmons
Governor, 1951–52

Oscar F. Neu
Governor, 1951–52

Malcolm G. Townsley
Governor, 1951–52

Lloyd Thompson
Governor, 1951–52

George W. Colburn
Governor, 1951

Charles R. Daily
Governor, 1951

E. M. Stifle
Governor, 1951

OFFICERS AND MANAGERS OF SECTIONS

ATLANTIC COAST: *Chairman*, E. M. Stifle; *Secretary-Treasurer*, H. C. Milholland; *Managers*, E. A. Bertram, H. D. Bradbury, H. A. Chinn, E. Dudley Goodale, D. B. Joy, R. G. Mann

CENTRAL: *Chairman*, G. W. Colburn; *Secretary-Treasurer*, C. E. Heppberger; *Managers*, E. E. Bickel, E. W. D'Arcy, R. E. Lewis, H. T. Nuttall, Lloyd Thompson, M. G. Townsley

PACIFIC COAST: *Chairman*, C. R. Daily; *Secretary-Treasurer*, Vaughan Shaner; *Managers*, L. W. Aicholtz, F. G. Albin, L. D. Grignon, W. F. Kelley, R. E. Lovell, E. H. Reichard

STUDENT CHAPTER OFFICERS

NEW YORK UNIVERSITY: *Chairman*, William F. Boden; *Secretary-Treasurer*, Gerald I. Rosenfeld

UNIVERSITY OF SOUTHERN CALIFORNIA: *Chairman*, Melvin R. Kells; *Secretary-Treasurer*, Eric T. Sjolander

Melvin R. Kells
Chairman, University of Southern California

William F. Boden
Chairman,
New York University

Treasurer's Report

January 1—December 31, 1950

Cash		
Cash on Deposit, Chase National Bank, January 1, 1950	$ 6,131.44	
Net Receipts	23,962.48	
Cash on Deposit—December 31, 1950	30,093.92	
Petty Cash Fund	200.00	
Total Cash on Hand and in Bank		$ 30,293.92
Investments		
Savings Accounts, January 1, 1950	$15,704.36	
Add: Additional Investments	15,000.00	
Interest Credited	715.35	
Savings Accounts, December 31, 1950	31,419.71	
U.S. Government Bonds (at cost)	60,000.00	
Total Investments		91,419.71
Total Cash and Investments, December 31, 1950		$121,713.63

Respectfully submitted,
FRANK E. CAHILL, JR., *Treasurer*

Summary of Financial Condition

December 31, 1950

Assets (What Your Society Owns)	
Cash on Hand and in Bank	$ 30,293.92
Savings Accounts	31,419.71
U.S. Government Bonds (at cost)	60,000.00
Accounts Receivable	8,349.99
Test Film Inventory	4,874.91
Test Film Equipment (depreciated value)	3,730.85
Office Furniture and Equipment (memo value)	1.00
Prepaid Expenses	46.88
Total Assets	$138,717.26
Liabilities (What Your Society Owes)	
Accounts Payable	$ 4,814.21
Due to Customers	430.19
Membership Dues Received in Advance	13,675.61
N.Y.C. Sales Tax Payable	9.18
Reserve for 1950 Five-Year Index	2,500.00
Total Liabilities	$ 21.429.19
Members' Equity (What Your Society Is Worth)	117,288.07
Total Liabilities and Members' Equity	$138,717.26

Statement of Income and Expenses

January 1—December 31, 1950

Test Film Operations		
Total Test Film Sales	$88,468.77	
Cost of Test Films Sold	46,616.71	
Net Income From Test Film Operations		$41,852.06
Publications Operations		
Total Publications Income	$18,989.38	
Total Cost of Publications	36,536.36	
Net Loss From Publications Operations		(17,546.98)
Other Operations		
Income From Other Operations	$ 821.95	
Cost of Other Operations	969.15	
Net Loss From Other Operations		(147.20)
Other Income		
Membership Dues		59,358.81
Interest Earned		2,165.35
Total Operating Income		$85,682.04
Operating Expenses		
Engineering	$10,015.09	
Non-Engineering	2,229.66	
Administrative	39,249.60	
Officers	94.75	
Sections and Chapters	2,250.00	
Affiliations	1,135.00	
Conventions (Net)	(498.98)	
Total Operating Expenses		54,475.12
Net Operating Income		$31,206.92
Other Deductions		
Depreciation of Test Film Equipment	$ 3,730.86	
Provision for 1950 Five-Year Index	500.00	
Total Other Deductions		4,230.86
Excess of Income over Expenses		$26,976.06

The foregoing financial statements were prepared from the records of the Society for the year 1950 and reflect the results of operations for that year. The records and financial statements were audited for the year ended December 31, 1950, by Wilbur A. Smith, Certified Public Accountant, New York City, and are in conformity with that audit.

Ralph B. Austrian, Financial Vice-President

Membership Report

For Year Ended December 31, 1950

	Hon.	Sust.	Fel.	Act.	Assoc.	Stud.	Total
Membership, January 1, 1950	2	67	187	871	1800	220	3147
New Members	1	12		134	237	80	464
Reinstatements		9	3	5	8	1	26
	3	88	190	1010	2045	301	3637
Resignations		−5		−22	−15	−11	−53
Deceased			−2	−5	−2		−9
Delinquents		−4	−1	−59	−145	−83	−292
	3	79	187	924	1883	207	3283
Changes in Grade:							
Fellow to Honorary	1		−1				
Active to Fellow			13	−13			
Associate to Active				21	−21		
Student to Active				3		−3	
Student to Associate					21	−21	
Fellow to Active			−1	1			
Active to Associate				−4	4		
Active to Student				−1		1	
Membership, December 31, 1950	4	79	198	931	1887	184	3283

Nonmember Subscription Report

For Year Ended December 31, 1950

Subscriptions, January 1, 1950	488
New Subscriptions	718
	1206
Cutoffs and Expirations	631
Subscriptions, December 31, 1950	575

Awards

IN ACCORDANCE with the provisions of the Administrative Practices of the Society and the regulations for granting the Journal Award, the Progress Medal Award and the Samuel L. Warner Memorial Award, a list of names of previous recipients and the reasons for the awards are published annually in the JOURNAL as follows:

Journal Award

The Journal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

At the fall convention of the Society a Journal Award Certificate shall be presented to the author or to each of the authors of the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year.

Other papers published in the JOURNAL of the Society may be cited for Honorable Mention at the option of the Committee, but in any case should not exceed five in number.

The Journal Award shall be made on the basis of the following qualifications:

(1) The paper must deal with some technical phase of motion picture engineering.

(2) No paper given in connection with the receipt of any other Award of the Society shall be eligible.

(3) In judging of the merits of the paper, three qualities shall be considered, with the weights here indicated: (a) technical merit and importance of material, 45%; (b) originality and breadth of interest, 35%; and (c) excellence of presentation of the material, 20%.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

These regulations, a list of the names of those who have previously received the Journal Award, the year of each Award, and the titles of the papers shall be published annually in the JOURNAL of the Society. In addition, the list of papers selected for Honorable Mention shall be published in the JOURNAL of the Society during the year current with the Award.

The recipients are listed below by year, with the date of JOURNAL publication given after the title.

1934, P. A. Snell, "An introduction to the experimental study of visual fatigue," May 1933.

1935, L. A. Jones and J. H. Webb, "Reciprocity law failure in photographic exposure," Sept. 1934.

1936, E. W. Kellogg, "A comparison of variable-density and variable-width systems," Sept. 1935.

1937, D. B. Judd, "Color blindness and anomalies of vision," June 1936.

1938, K. S. Gibson, "The analysis and specification of color," Apr. 1937.

1939, H. T. Kalmus, "Technicolor adventures in cinemaland," Dec. 1938.

1940, R. R. McNath, "The surface of the nearest star," Mar. 1939.

1941, J. G. Frayne and Vincent Pagliarulo, "The effects of ultraviolet light on variable-density recording and printing," June 1940.

1942, W. J. Albersheim and Donald MacKenzie, "Analysis of soundfilm drives," July 1941.

1943, R. R. Scoville and W. L. Bell, "Design and use of noise-reduction bias systems," Feb. 1942 (Award made Apr. 1944).

1944, J. I. Crabtree, G. T. Eaton and M. E. Muehler, "Removal of hypo and silver salts from photographic materials as affected by the composition of the processing solutions," July 1943.

1945, C. J. Kunz, H. E. Goldberg and C. E. Ives, "Improvement in illumination efficiency of motion picture printers," May 1944.

1946, R. H. Talbot, "The projection life of film," Aug. 1945.

1947, Albert Rose, "A unified approach to the performance of photographic film, television pickup tubes, and the human eye," Oct. 1946.

1948, J. S. Chandler, D. F. Lyman and L. R. Martin, "Proposals for 16-mm and 8-mm sprocket standards," June 1947.

1949, F. G. Albin, "Sensitometric aspect of television monitor-tube photography," Dec. 1948.

1950, Frederick J. Kolb, Jr., "Air Cooling of Motion Picture Film for Higher Screen Illumination," Dec. 1949.

The present Chairman of the Journal Award Committee is Frederick J. Kolb, Jr.

Progress Medal Award

The Progress Medal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal may be awarded each year to an individual in recognition of any invention, research or development which, in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society may recommend persons deemed worthy of the Award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

A majority vote of the entire Committee shall be required to constitute an Award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

These regulations, a list of the names of those who have previously received the Medal, the year of each Award and a statement of the reason for the Award shall be published annually in the JOURNAL of the Society.

Awards have been made as follows:

1935, E. C. Wente, for his work in sound recording and reproduction, Dec. 1935.

1936, C. E. K. Mees, for his work in photography, Dec. 1936.

1937, E. W. Kellogg, for his work in sound reproduction, Dec. 1937.

1938, H. T. Kalmus, for his work in developing color motion pictures, Dec. 1938.

1939, L. A. Jones, for his scientific researches in photography, Dec. 1939.

1940, Walt Disney, for his contributions to motion picture photography and sound recording of feature and short cartoon films, Dec. 1940.

1941, G. L. Dimmick, for his development activities in motion picture sound recording, Dec. 1941.

No Awards were made in 1942 and 1943.

1944, J. G. Capstaff, for his research and development of films and apparatus used in amateur cinematography, Jan. 1945.

No Awards were made in 1945 and 1946.

1947, J. G. Frayne, for his technical achievements and the documenting of his work in addition to his contributions to the field of education and his inspiration to his fellow engineers, Jan. 1948.

1948, Peter Mole for his outstanding achievements in motion picture studio lighting which set a pattern for lighting techniques and equipment for the American motion picture industry, Jan. 1949.

1949, Harvey Fletcher for his outstanding contributions to the art of recording and reproducing of sound for motion pictures, Oct. 1949.

1950, V. K. Zworykin, for his outstanding contributions to the development of television, Dec. 1950.

The present Chairman of the Progress Medal Award Committee is D. B. Joy.

Samuel L. Warner Memorial Award

Each year the President shall appoint a Samuel L. Warner Memorial Award Committee consisting of a chairman and four members. The chairman and committee members must be Active Members or Fellows of the Society. In considering candidates for the Award, the committee shall give preference to inventions or developments occurring in the last five years. Preference should also be given to the invention or development likely to have the widest and most beneficial effect on the quality of the reproduced sound and picture. A description of the method or apparatus must be available for publication in sufficient detail so that it may be followed by anyone skilled in the art. Since the Award is made to an individual, a development in which a group participates should be considered only if one person has contributed the basic idea and also has contributed substantially to the practical working out of the idea. If, in any year, the committee does not consider any recent development to be more than the logical working out of details along well-known lines, no recommendation for the Award shall be made. The recommendation of the committee shall be presented to the Board of Governors at the July meeting.

The purpose of this Award is to encourage the development of new and improved methods or apparatus designed for sound-on-film motion pictures, including any step in the process.

Any person, whether or not a member of the Society of Motion Picture and Televison Engineers, is eligible to receive the Award.

The Award shall consist of a gold medal suitably engraved for each recipient. It shall be presented at the Fall Convention of the Society, together with a bronze replica.

These regulations, a list of those who previously have received the Award, and a statement of the reason for the Award shall be published annually in the Journal of the Society. The recipients have been:

1947, J. A. Maurer, for his outstanding contributions to the field of high-quality 16-mm sound recording and reproduction, film processing, development of 16-mm sound test films, and for his inspired leadership in industry standardization (citation published, Jan. 1948).

1948, Nathan Levinson, for his outstanding work in the field of motion picture sound recording, the intercutting of variable-area and variable-density sound tracks, the commercial use of control track for extending volume range, and the use of the first soundproof camera blimps (citation published, Jan. 1949).

1949, R. M. Evans, for his outstanding work in the field of color motion picture films, including research on visual effects in photography and development work on commercial color processes (citation published, Oct. 1949).

1950, Charles R. Fordyce, for his efforts and the achievement of the development of triacetate safety base film (citation published, Dec. 1950).

The present Chairman of the Samuel L. Warner Memorial Award Committee is Glenn L. Dimmick.

Addendum—1951 Nominations

'Voting' members of the Society should note that in addition to those listed on p. 250 of the February Journal, there should be the office of Engineering Vice-President, of which Fred T. Bowditch is the incumbent.

Journals Out of Stock: The Society's stock of Journal issues for March, Part II, July, August, September, 1949, and February, 1950, has been exhausted as a result of an unexpected increase in demand and the Society's Headquarters is anxious to purchase a stock of each. Members or libraries having extra copies available are invited to send them in. The going price is 75c.

Engineering Activities

TV Studio Lighting

Members of the Television Studio Lighting Committee, under the chairmanship of Dick Blount, met on March 15, 1951, and made strides in their ambitious program. At the previous meeting three subcommittees had been formed to study and report on: (1) power distribution and control, (2) lighting techniques, and (3) terminology and measurements. These problems were discussed and the chairmen of the three subcommittees (H. A. Kliegl, H. M. Gurin and R. L. Zahour) agreed to prepare written reports to form the basis of the Committee's report scheduled for presentation during the Spring Convention.

The scope of the Power Distribution and Control Subcommittee was expanded to include also a study of the mechanical supports required for both power and lamp equipment. To indicate this broader scope, the name of the group was changed to Lighting Facilities.

Definitions of three general categories of lighting (1, base; 2, accent; and 3, effects) were reached after appreciable discussion. The terminology Subcommittee was then asked to study the many subdivisions of accent lighting and prepare definitions of the terms, now in use or proposed, for future consideration of the Committee.

TV Leader

The Films for Television Leader Subcommittee, chaired by C. L. Townsend, met in late March, 1951, and continued their efforts to secure agreement on a standard threading leader for both the film and television industries. At previous meetings it has been agreed that the best test of the new leader would be its widespread use in either field. It was noted there are three television studios now using the proposed new leader (CBS, NBC, WOR) and ABC is about to start using it. In addition, several New York theater projectionists had studied the Leader and gave it their wholehearted approval.

In considering future action most useful for achieving industry-wide agreement on the Leader, it was agreed that widespread publicity on the new Leader was in order. This is to be accomplished by publication in the JOURNAL of an interim Committee report prepared by the Chairman.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Barkofsky, Ernest C., Head Physicist, Microsecond Photography Section, U.S. Naval Ordnance Test Station. **Mail:** 71-B Rowe St., China Lake, Calif. (**A**)

Battey, Robert S., Development Engineer, EastmanKodak Co. **Mail:** 1560 Fairport-Webster Road, Penfield, N.Y. (**A**)

Bellamy, Ben C., Civil Engineer, Bellamy & Sons. **Mail:** Box 37, Laramie, Wyo. (**A**)

Bodkins, Arthur, Commercial, Ciné and Still Photographer. **Mail:** 69 Locust St., Winthrop, Mass. (**A**)

Brown, Warner M., Film Technician, Precision Film Laboratory. **Mail:** 111 Sullivan St., New York 12, N.Y. (**A**)

Cameron, James R., Jr., Projectionist, Tropicaire Drive-In Theater. **Mail:** 7400 S.W. 19 Street Road, Miami, Fla. (**A**)

Dunn, Donald E., Motion Picture Specialist—Editor, Sound Recording Engineer and Writer, North American Aviation, Inc. **Mail:** 5726 Budlong Ave., Los Angeles 37, Calif. (**A**)

Eddy, William C., President, Television Associates, Inc. **Mail:** E. Michigan St., Michigan City, Ind. (**M**)

Ervin, Russell T., Associate Producer, Grantland Rice Sportlight. **Mail:** 22 W. 48 St., New York, N.Y. (**M**)

Fischer, H. W., Technical Service Manager, Carl Zeiss, Inc. **Mail:** 3321 Bruckner Blvd., Apt. 3F, New York 61, N.Y. **(A)**

Flaherty, John P., Moving Picture Projectionist, Radio and Television Technician. **Mail:** 761 Harrison Ave., Louisville, Ky. **(M)**

Frenette, Charles, Television Technical Director, Canadian Broadcasting Corp. **Mail:** 5200 Hingston Ave. N.D.G., Montreal, Canada. **(A)**

Galante, James W., Director of Photography, American Television, Inc. **Mail:** 4738 W. Congress St., Chicago 44, Ill. **(A)**

Gibson, Gordon O., Theater Equipment Engineer, Atlas Theatre Supply Co. **Mail:** 425 Van Braam St., Pittsburgh, Pa. **(A)**

Grunkemeyer, George W., Photographer. **Mail:** P.O. Box 899, 444 West Alger, Sheridan, Wyo. **(A)**

Harrold, Donald O., Sound Technician, Telefilm, Inc. **Mail:** 1349 Cherokee Ave., Hollywood 28, Calif. **(A)**

Heynick, Benjamin, Mechanical Engineer, Federal Manufacturing & Engineering Corp. **Mail:** 286 Eastern Parkway, Brooklyn 25, N.Y. **(A)**

Hipple, Paul N., Motion Picture Projectionist, Jay Emanuel (Senate Theatre). **Mail:** Linden Ave., Marysville, Pa. **(A)**

Hornstein, Hal, Manager, Joe Hornstein, Inc. **Mail:** 712 N.E. First Ave., Miami, Fla. **(A)**

Hotin, Roland A., Photographic Technologist, Bureau of Ordnance, U.S. Navy. **Mail:** BOQ—"C" NOTS, China Lake, Calif. **(M)**

Hunt, Clyde M., Director of Engineering and Operations, WTOP, Inc., Warner Building, Washington 4, D.C. **(M)**

Johnson, F. Eugene, Sales Service, Eastman Kodak Co., 343 State St., Rochester, N.Y. **(M)**

Jones, Ernest D., Motion Picture Cameraman, Boeing Airplane Co. **Mail:** 4508 W. Mass, Seattle 6, Wash. **(A)**

Klein, Jerry, Video Recording Engineer, American Broadcasting Co. **Mail:** 513 Kings Highway, Brooklyn 23, N.Y. **(A)**

Kogel, Henry, Staff Engineer, SMPTE, **Mail:** 500 A Grand St., New York 2, N.Y. **(A)**

Komow, Victor H., Free-lance Cameraman, Film Director and Soundman. **Mail:** 248 E. 34 St., New York 16, N.Y. **(A)**

Love, Edgar J., General Engineering Manager, WWJ, The Detroit News. **Mail:** 9264 Boleyn, Detroit 24, Mich. **(M)**

Martin, Leslie, U.S. Navy. **Mail:** Box #48, U.S. Naval Station, Navy #230, c/o Postmaster, Seattle, Wash. **(A)**

McIntire, Harry R., Hollywood Sound Inst. **Mail:** 1023 N. Edgemont St., Los Angeles, Calif. **(S)**

Morrison, Arthur Q., Laboratory Manager, Society for Visual Education. **Mail:** 1934 Ridge Road, Homewood, Ill. **(A)**

Motyl, Ernest C., Production Supervisor, J. Walter Thompson Co., 420 Lexington Ave., New York 17, N.Y. **(A)**

Nass, Leonard I., Polytechnic Inst. of Brooklyn. **Mail:** 1065 Jerome Ave., Bronx 52, N.Y. **(S)**

Patterson, Victor E., Custom-built Laboratory Equipment and Camera Conversions. **Mail:** 5805 44 Ave., Hyattsville, Md. **(M)**

Radsliff, John L., Senior Electronics Technician, University of California Radiation Laboratory. **Mail:** 1134 Delaware, Apt. C., Berkeley, Calif. **(A)**

Raguse, Roy H., Sound Recording Engineer, Hal Roach Studios. **Mail:** 3518 S. Sycamore Ave., Los Angeles 16, Calif. **(A)**

Read, Morton H., Film Producer, Bay State Film Productions, Inc. **Mail:** 458 Bridge St., Springfield, Mass. **(M)**

Ricci, Eduardo J., New York University. **Mail:** 10 Park Terrace East, New York 34, N.Y. **(S)**

Rossini, Dino, President, Radiant Laboratories, Inc. **Mail:** 340 E. 66 St., New York 21, N.Y. **(M)**

Ruley, David, Television and Film Cameraman, Columbia Broadcasting System. **Mail:** 6 Field End Lane, Tuckahoe 7, N.Y. **(A)**

Shields, Daniel W., Film Director, WFMY-TV. **Mail:** 908 Park Avenue, Greensboro, N.C. **(A)**

Smith, Arthur Maxwell, Technical Supervisor, British Paramount News. **Mail:** 14 Lynton Ave., N. Finchley, London, England. **(M)**

Smith, Carl E., Vice-President in Charge of Engineering, United Broadcasting Co. **Mail:** 5000 Euclid Ave., Cleveland 3, Ohio. **(M)**

Strickland, John LeRoy, Projectionist, Herbert Rosner Co. **Mail:** 849 W. 94 St., Los Angeles 44, Calif. **(A)**

Uecke, Edward H., Electronics Engineer, Capitol Records, Inc. **Mail:** 4529 Mont Eagle Place, Los Angeles 41, Calif. **(A)**

Weller, Donald A., Radio Engineer, Chief Engineer, WISN. **Mail:** 819 E. Beaumont Ave., Milwaukee 11, Wis. **(M)**

Westfall, Ralph, Technical Assistant, Eastman Kodak Co. **Mail:** 3740 Willowcrest Ave., North Hollywood, Calif. **(A)**

CHANGES IN GRADE

Decker, H. M., Motion Picture Projectionist, Sunset Drive-In Theater. **Mail:** 1421 Garden St., San Luis Obispo, Calif. **(S)** to **(A)**

Walker, Algernon G., Newsreel Cameraman, KITV. **Mail:** 13436 Wingo St., Pacoima, Calif. **(S)** to **(A)**

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

This new portable television camera and transmitting station, designed to operate in the field as a one-man back-pack unit, was demonstrated by L. E. Flory, of the RCA Laboratories, at a meeting of the Institute of Radio Engineers in New York on March 22. In the illustration, J. E. Dilley, of the RCA Laboratories staff, is demonstrating, and standing to the right is Dr. V. K. Zworykin, Vice-President and Technical Consultant of the RCA Laboratories, who directed research and development work on the equipment.

Weighing only 53 lb, the back-pack station is planned to function with its own battery-power supply. Numerous applications for the new equipment are foreseen by RCA research engineers, including news coverage, with television-equipped reporters flashing pictures and commentary directly to editorial rooms, and remote industrial viewing and control.

The new transmitter operates in conjunction with a control station which may be located as far as a mile from the camera. Signals corresponding to the scene being televised are transmitted to the control point on an ultra-high frequency with a power of two watts. In addition to acting as a monitor for the televised picture, the control point performs two other functions. It sends out a stream of pulses which stabilize the camera and can be used also to issue vocal instructions to the cameraman.

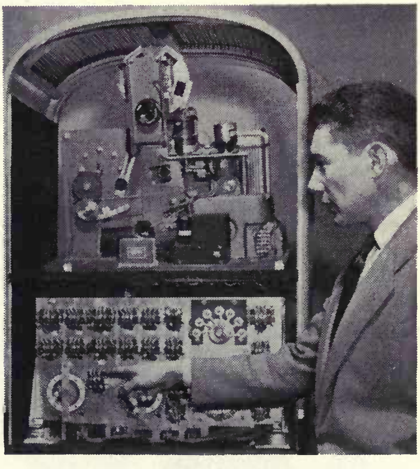
Recent developments in the design of pencil-sized tubes and other sub-miniature components made possible the relatively small bulk and weight of the equipment. Two small antennas extend from the top of the pack and are used respectively to transmit the picture signal to a base station and to receive voice and control signals from that same point.

The camera is an adaptation of the RCA industrial TV camera using the Vidicon tube. As an added feature, the camera includes a miniature kinescope picture tube which serves as a view-finder for the cameraman.

The equipment contains 42 tubes which, with their associated circuits, provide all synchronizing frequencies for a standard 525-line, 30-frame interlaced television picture. Included in the unit are the battery-operated power supply, deflecting circuits, amplifiers, and a radio receiver for operator instruction from the control point. A single battery operates the portable station for about 1½ hr.

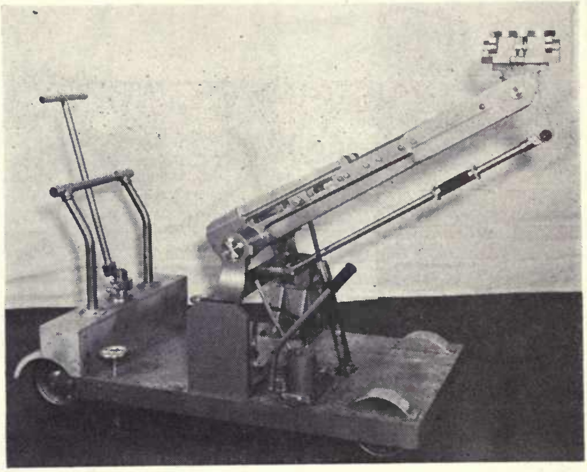
The narrator-camerman's voice is picked up and transmitted through the combination of a small microphone built into the camera case and an ingenious electronic circuit which adds the voice signals to the picture signals as they are radiated to the control point.

Motion pictures team up with an electromechanical scoring device that metes out penalty points for automobile driver errors in the Automograph, an automatic driver-trainer developed by the Automograph Company, 30 Broad Street, New York, and used by the Aetna Casualty and Surety Co. which calls it the Aetna Roadometer in a national automobile safety campaign. The complete equipment projects a three-minute motor trip, records penalty points for each error in steering, braking, signaling, speed control and horn blowing, totals the driver's score and prints a report card with individual scores for each of nine separate driving problems. Also shown here is the "mechanical brain" with its lid off.



Scoring is accomplished by a series of counters and mechanical accumulators that compare the driver's actual performance over a period of 180 successive time units, with a theoretically "perfect" driver. A perfect match in every case gives a total score of zero, while the poorest score is 180. The signals to be matched are in the sound track area, film is a loop of 16-mm color, and operator instructions and examples of the consequences of improper driving are projected from a series of 2 × 2 color slides.

The Hydrolift Dolly is basically designed to permit fast changeover from high to low camera positions, or vice versa. The required time is reported as 5 sec for high to low and 20 sec for low to high. It is manufactured by National Cine Equipment, Inc., 20 W. 22d St., New York 10.

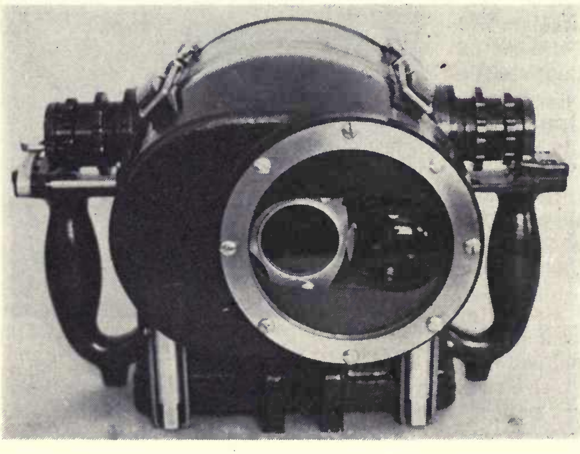


The dolly weighs about 395 lb and has these dimensions:

Over-all length	
With arm in lowered position	75 in.
With arm in raised position	55 in.
Over-all width	28 in.
Maximum height	
To top of tripod head mounting base	69 in.
Minimum height	
To top of tripod head mounting base	22 in.

The camera boom arm lift is operated by a hydraulic cylinder and powered by a manually operated pump. Downward movement is accomplished by gravity action on the oil cylinder. Rate of descent is controlled by a vernier screw arrangement, and the arm which can be stopped at any position is automatically locked by the hydraulic system.

The dolly is designed to accommodate any 16-mm or 35-mm professional camera or blimp, as well as TV cameras, the maximum load weight being 250 lb. The dolly can be equipped with an electrical hydraulic pump system to eliminate the manual operation.



An underwater motion picture camera and diving equipment, designed to permit a photographer to remain under water for an hour to an hour and a half, are now available from Fenjohn Underwater Photo & Equipment Co., Ardmore, Pa. That organization has been custom-making underwater photographic equipment for 22 years and is now producing the 16-mm camera in limited quantities. The assembly includes a Bell & Howell GSAP camera of 50-ft capacity, with an Elgeet

wide-angle 13-mm focal length $f/1.5$ lens, four filter mounts, an electric drive (self-contained batteries) which will operate approximately 1000 ft at sound speed and what Fenjohn reports are the only effective underwater color filters produced. Aperture, focus, filter and speed settings (of 12, 16, 24, 32, 48 or 64) may be made under water. Aperture, focus and filter settings and footage counter may be seen through the large viewfinder. The operator's thumb works the trigger. The housing is cast aluminum, and the equipment weighs 21 lb in the air and 3¾ lb under water. The camera is easily handled from a small boat, and it is reported that it can be hauled up, reloaded and returned to the swimmer in 30 sec.

Fenjohn says that good commercial-quality pictures may be made at 10 to 20 ft below the surface. The price is $1,790.

The Aqua-Lung, which was described in "U.S. Naval Underwater Cinematography Techniques," by R. R. Conger, (*Jour. SMPTE*, vol. 55, pp. 627–634, Dec. 1950), is a free swimming unit, light and easily transported, using compressed air. The Fenjohn Company, which distributes it, says that dives of over 400 ft have been accomplished with the lung and that it is standard equipment for the French Navy. They say that it "should be part of everyone's gear who is around the water for both enjoyment and practical purposes." It costs $139.50, delivered anywhere in the United States.

Meetings of Other Societies

American Physical Society, Apr. 26–28, Washington, D.C.

Acoustical Society of America, May 10–12, Washington, D.C.

American Physical Society, June 14–16, Schenectady, N.Y.

American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Illuminating Engineering Society, Aug. 27–30, Washington, D.C.

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

- Acoustical Society of America, Oct. 23–25
- Optical Society of America, Oct. 23–25
- Society of Rheology, Oct. 24–26
- American Physical Society, Oct 25–27
- American Association of Physics Teachers, Oct. 25–27

Employment Service

POSITION AVAILABLE: Mechanical engineer, preferably experienced in design 35-mm projectors; salary open; state qualifications and salary requirements for permanent position; write to: H. T. Matthews, President, Motiograph, Inc., 4431 W. Lake St., Chicago 24, Ill.

Committees of the Society

As of March 15, 1951

Administrative Committees

ADMISSIONS. *To pass upon all applications for membership, applications for transfer, and to review the Student and Associate membership list periodically for possible transfer to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.*

E. A. Bertram, *Chairman, East,* DeLuxe Laboratories, 850 Tenth Ave., New York 19

C. R. Keith	W. B. Lodge	E. I. Sponable

Bertel J. Kleerup, *Chairman, Central,* Society for Visual Education, 1345 W. Diversey Parkway, Chicago 14, Ill.

E. E. Bickel	Lloyd Thompson	M. G. Townsley

N. L. Simmons, *Chairman, West,* Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif.

T. T. Moulton	E. H. Reichard	Petro Vlahos

BOARD OF EDITORS. *To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the* JOURNAL.

Arthur C. Downes, *Chairman,* 2181 Niagara Dr., Lakewood 7, Ohio

G. M. Best	A. M. Gundelfinger	G. E. Matthews	R. T. Van Niman
L. B. Browder	C. W. Handley	Pierre Mertz	J. H. Waddell
C. R. Fordyce	A. C. Hardy	H. W. Pangborn	D. R. White
L. D. Grignon	C. R. Keith	N. L. Simmons	

EUROPEAN ADVISORY COMMITTEES. *To act as liaison between the general Society and European firms, individuals, and organizations interested in motion picture and television engineering. To report to the Society on such affairs in Europe, on new technical developments, and to assist the Papers Committee in soliciting papers for publication in the* JOURNAL.

I. D. Wratten, *Chairman (British Division),* Kodak, Ltd., Kingsway, London, England

R. H. Cricks	W. M. Harcourt	L. Knopp	A. W. Watkins

L. Didiée, *Chairman (Continental Division)* Association Francaise des Ingénieurs et Techniciens du Cinéma, 92 Champs-Elysées, Paris (8e), France

R. Alla	M. Certes	S. Feldman	M. Terrus
R. Bocquel	J. Cordonnier	J. Fourrage	J. Vivié
		G. Mareschal	M. Yvonnet

FELLOW AWARD. *To consider publications of Active members as candidates for elevation to Fellow, and to submit such nominations to the Board of Governors.*

Earl I. Sponable, *Chairman,* Movietonews, Inc., 460 W. 54 St., New York 19

Ralph B. Austrian	F. T. Bowditch	Robert M. Corbin	W. C. Kunzmann
Herbert Barnett	F. E. Cahill	Charles R. Daily	Peter Mole
	George W. Colburn	John G. Frayne	E. M. Stifle

HISTORICAL AND MUSEUM. *To collect facts and assemble data relating to the historical development of the motion picture and television industries, to encourage pioneers to place their work on record in the form of papers for publication in the* JOURNAL, *and to place in suitable depositories equipment pertaining to the industry.*

E. A. Bertram, *Chairman,* DeLuxe Laboratories, Inc., 850 Tenth Ave., New York 19

(Under Organization)

HONORARY MEMBERSHIP. *To search diligently for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion picture industry and are thus worthy of becoming Honorary members of the Society.*

Gordon Chambers, *Chairman,* Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

Carroll H. Dunning	Philo T. Farnsworth	Barton Kreuzer	Loren L. Ryder

JOURNAL AWARD. *To recommend to the Board of Governors the author or authors of the most oustanding paper originally published in the* JOURNAL *during the preceding calendar year to receive the Society's* JOURNAL *Award.*

F. J. Kolb, Jr., *Chairman,* Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

Paul Arnold	A. N. Goldsmith	Joseph H. Spray

NOMINATIONS. *To recommend nominations to the Board of Governors for annual election of officers and governors.*

Earl I. Sponable, *Chairman,* Movietonews, Inc., 460 W. 54 St., New York 19

Herbert Barnett	Nathan D. Golden	William B. Lodge	Charles H. Percy
G. L. Carrington	D. E. Hyndman	Peter Mole	Richard Warn

PAPERS. *To solicit papers and provide the program for semiannual conventions, and make available to local sections for their meetings papers presented at national conventions.*

Edward S. Seeley, *Chairman,* Altec Service, 161 Sixth Ave., New York 13

Joseph E. Aiken, *Vice-Chairman,* 116 No. Galveston St., Arlington, Va.

F. G. Albin, *Vice-Chairman,* American Broadcasting Co., Station KECA-TV, 4151 Prospect Ave., Hollywood, Calif.

G. G. Graham, *Vice-Chairman,* National Film Board of Canada, John St., Ottawa, Canada

W. H. Rivers, *Vice-Chairman,* Eastman Kodak Co., 342 Madison Ave., New York 17

R. T. Van Niman, *Vice-Chairman,* 4441 Indianola Ave., Indianapolis, Ind.

John H. Waddell, *Vice-Chairman,* Wollensak Optical Co., 850 Hudson Ave., Rochester, N.Y.

A. C. Blaney	Farciot Edouart	P. A. Jacobson	W. J. Morlock
Richard Blount	F. L. Eich	William Kelley	Herbert Pangborn
R. P. Burns	Dudley Goodale	E. P. Kennedy	Edward Schmidt
Philip Caldwell	Charles Handley	George Lewin	N. L. Simmons
F. O. Calvin	R. N. Harmon	E. C. Manderfeld	S. P. Solow
Howard Chinn	Scott Helt	Glenn Matthews	J. G. Stott
J. P. Corcoran	C. E. Heppberger	Pierre Mertz	W. L. Tesch
G. R. Crane	J. K. Hilliard	James Middlebrooks	S. R. Todd
E. W. D'Arcy	L. Hughes	Harry Milholland	M. G. Townsley

PROGRESS. *To prepare an annual report on progress in the motion picture and television industries.*

C. W. Handley, *Chairman,* 1960 West 84 St., Los Angeles 44, Calif.

J. E. Aiken	J. W. Duvall	G. R. Groves	W. A. Mueller
W. L. Bell	T. J. Gibbons	W. F. Kelley	B. F. Perry
P. G. Caldwell	G. H. Gordon	R. E. Lewis	E. H. Reichard
			W. L. Tesch

PROGRESS MEDAL AWARD. *To recommend to the Board of Governors a candidate who by his inventions, research, or development has contributed in a significant manner to the advancement of motion picture technology, and is deemed worthy of receiving the Progress Medal Award of the Society.*

David B. Joy, *Chairman*, National Carbon Division, 30 E. 42 St., New York 17

Max Batsel	F. H. McIntosh	George Mitchell	D. R. White

DAVID SARNOFF AWARD. *To recommend to the Board of Governors a candidate who has done outstanding work in some technical phase of the broad field of television or in any similar phase of theater television, whether in research, development, design, manufacture or operation.*

Pierre Mertz, *Chairman*, Bell Telephone Laboratories, Inc., 463 West St., New York 14

Raymond L. Garman	T. T. Goldsmith	William B. Lodge

SUSTAINING MEMBERSHIP. *To solicit new sustaining members and thereby obtain adequate financial support required by the Society to carry on its technical and engineering activities.*

Earl I. Sponable, *Chairman*, Movietonews, Inc., 460 W. 54 St., New York 19

D. B. Joy	S. P. Solow

SAMUEL L. WARNER AWARD. *To recommend to the Board of Governors a candidate who has done the most outstanding work in the field of sound motion picture engineering, in the development of new and improved methods or apparatus designed for sound motion pictures, including any steps in the process, and who, whether or not a Member of the Society of Motion Picture and Television Engineers, is deemed eligible to receive the Samuel L. Warner Memorial Award of the Society.*

Glenn L. Dimmick, *Chairman*, RCA Victor Division, Front and Cooper Sts., Camden, N.J.

Lloyd Goldsmith	John Hilliard	John Maurer	Otto Sandvik

Engineering Committees

COLOR. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of color motion picture processes, accessory equipment, studio lighting, selection of studio set colors, color cameras, color motion picture films, and general color photography. (File 10)*

H. H. Duerr, *Chairman*, Ansco, Binghamton, N.Y.

R. H. Bingham	R. O. Drew	L. T. Goldsmith	C. F. J. Overhage
M. R. Boyer	A. A. Duryea	A. M. Gundelfinger	W. E. Pohl
H. E. Bragg	R. M. Evans	W. W. Lozier	G. F. Rackett
O. O. Ceccarini	J. G. Frayne	A. J. Miller	L. E. Varden

FILM DIMENSIONS. *To make recommendations and prepare specifications on those film dimensions which affect performance and interchangeability, and to investigate new methods of cutting and perforating motion picture film in addition to the study of its physical properties. (File 15)*

E. K. Carver, *Chairman*, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

E. A. Bertram	A. M. Gundelfinger	W. E. Pohl	William Wade
A. F. Edouart	W. G. Hill	N. L. Simmons	Fred Waller
	A. J. Miller	M. G. Townsley	D. R. White

FILM-PROJECTION PRACTICE. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture projection equipment, projection rooms, film-storage facilities, stage arrangement, screen dimensions and placement, and maintenance of loudspeakers to improve the quality of reproduced sound and the quality of the projected picture in the theater. (File 20)*

M. D. O'Brien, *Chairman,* Projection and Sound Dept., Loew's Theaters, 1540 Broadway, New York 19

C. S. Ashcraft	L. W. Davee	G. T. Lorance	Paul Ries
Frank Cahill	C. L. Greene	Robert Lucas	Harry Rubin
Merle Chamberlin	R. H. Heacock	D. F. Lyman	Ben Schlanger
Joseph Clayton	Henry Heidegger	H. T. Matthews	J. W. Servies
	C. F. Horstman	Stanley Perry	S. R. Todd

FILMS FOR TELEVISION. *To make recommendations and prepare specifications on all phases of the production, processing and use of film made for transmission over a television system excluding video transcriptions. (File 80)*

R. L. Garman, *Chairman,* General Precision Laboratory, Inc., 63 Bedford Road, Pleasantville, N.Y.

R. O. Drew	H. R. Lipman	R. M. Morris	John G. Stott
Richard Hodgson	Pierre Mertz	R. C. Rheineck	C. L. Townsend
S. E. Howse	H. C. Milholland	H. J. Schlafly	L. F. Transue
R. Johnston	G. C. Misener	N. L. Simmons	T. G. Veal

HIGH-SPEED PHOTOGRAPHY. *To make recommendations and prepare specifications for the construction, installation, operation, and servicing of equipment for photographing and projecting pictures taken at high repetition rates or with extremely short exposure times. (File 25)*

J. H. Waddell, *Chairman.* Wollensak Optical Co., 78 Brunswick St., Rochester 7, N.Y.

H. E. Edgerton, *Vice-Chairman,* Dept. of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass.

E. A. Andres, Sr.	R. E. Farnham	N. C. Lipton	D. H. Peterson
K. M. Baird	W. R. Fraser	C. D. Miller	Earl Quinn
D. M. Beard	Eleanor Gerlach	A. P. Neyhart	M. L. Sandell
H. W. Crouch	C. C. Herring	W. S. Nivison	Kenneth Shaftan
C. H. Elmer	H. M. Lester	Brian O'Brien	C. W. Wyckoff
			A. M. Zarem

LABORATORY PRACTICE. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture printers, processing machines, inspection projectors, splicing machines, film-cleaning and treating equipment, rewinding equipment, any type of film-handling accessories, methods, and processes which offer increased efficiency and improvements in the photographic quality of the final print. (File 30)*

J. G. Stott, *Chairman,* Du Art Film Laboratories, 245 West 55 St., New York, N.Y.

V. D. Armstrong	Gordon Chambers	C. F. LoBalbo	E. H. Reichard
H. L. Baumbach	I. M. Ewig	J. A. Maurer	V. C. Shaner
D. P. Boyle	T. M. Ingman	O. W. Murray	J. H. Spray
O. E. Cantor	P. A. Kaufman	W.H.Offenhauser, Jr.	Lloyd Thompson
		W. E. Pohl	Paul Zeff

MOTION PICTURE STUDIO LIGHTING AND PROCESS PHOTOGRAPHY. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of all types of studio and outdoor auxiliary lighting equipment, tungsten light and carbon-arc sources, lighting-effect devices, diffusers, special light screens, etc., to increase the general engineering knowledge of the art; and to make recommendations and prepare specifications on motion picture optical printers, process projectors (background process), matte processes, special process lighting technique, special processing machines, miniature-set requirements, special-effects devices, and the like, that will lead to improvement in this phase of the production art. (File 35)*

M. A. Hankins, *Chairman*, Mole-Richardson Co., 937 N. Sycamore Ave., Hollywood 38, Calif.

Richard Blount	Karl Freund	C. R. Long	D. W. Prideaux
J. W. Boyle	C. W. Handley	W. W. Lozier	Petro Vlahos

OPTICS. *To make recommendations and prepare specifications on all subjects connected with lenses and their properties. (File 40)*

R. Kingslake, *Chairman*, Eastman Kodak Co., Hawk Eye Works, Rochester 4, N.Y.

F. G. Back	I. C. Gardner	J. L. Maulbetsch	W. E. Pohl
A. A. Cook	J. W. Gillon	J. A. Maurer	L. T. Sachtleben
C. R. Daily	Grover Laube	G. A. Mitchell	O. H. Schade
		A. E. Murray	M. G. Townsley

PRESERVATION OF FILM. *To make recommendations and prepare specifications on methods of treating and storage of motion picture film for active, archival, and permanent record purposes, so far as can be prepared within both the economic and historical value of the films. (File 45)*

J. W. Cummings, *Chairman*, National Archives, Washington 25, D.C.

Henry Anderson	J. W. Dunham	G. Graham	N. F. Oakley
W. G. Brennan	C. R. Fordyce	A. C. Hutton	W. E. Pohl
	J. E. Gibson	J. B. McCullough	W. D. Stump

PROCESS PHOTOGRAPHY. *This Committee has been combined with the Motion Picture Studio Lighting Committee and will no longer be listed as a separate organization.*

SCREEN BRIGHTNESS. *To make recommendations, prepare specifications, and test methods for determining and standardizing the brightness of the motion picture screen image at various parts of the screen, and for special means or devices in the projection room adapted to the control or improvement of screen brightness. (File 55)*

W. W. Lozier, *Chairman*, National Carbon Div., Fostoria, Ohio

Herbert Barnett	L. T. Goldsmith	F. J. Kolb	B. A. Silard
H. J. Benham	L. D. Grignon	W. F. Little	Allen Stimson
F. E. Carlson	A. J. Hatch, Jr.	L. J. Patton	C. R. Underhill, Jr.
M. H. Chamberlin	L. B. Isaac	Leonard Satz	H. E. White
E. R. Geib	W. F. Kelley	J. W. Servies	A. T. Williams
			D. L. Williams

16-MM AND 8-MM MOTION PICTURES. *To make recommendations and prepare specifications for 16-mm and 8-mm cameras, 16-mm sound recorders and sound-recording practices, 16-mm and 8-mm printers and other film laboratory equipment and practices, 16-mm and 8-mm projectors, splicing machines, screen dimensions and placement, loudspeaker output and placement, preview or theater arrangements, test films, and the like, which will improve the quality of 16-mm and 8-mm motion pictures. (File 60)*

H. J. Hood, *Chairman*, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

H. W. Bauman	E. W. D'Arcy	W. W. Lozier	A. G. Petrasek
W. C. Bowen	G. A. Del Valle	D. F. Lyman	A. C. Robertson
F. L. Brethauer	J. W. Evans	W. C. Miller	L. T. Sachtleben
F. E. Brooker	C. R. Fordyce	J. R. Montgomery	H. H. Strong
F. E. Carlson	John Forrest	J. W. Moore	Lloyd Thompson
S. L. Chertok	R. C. Holslag	W. H. Offenhauser, Jr.	M. G. Townsley
	Rudolf Kingslake		

SOUND. *To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture film, sound recorders, re-recorders, and reproducing equipment, methods of recording sound, sound-film processing, and the like, to obtain means of standardizing procedures that will result in the production of better uniform quality sound in the theater.* (*File 65*)

L. T. Goldsmith, *Chairman*, Warner Brothers Pictures, Burbank, Calif.

G. L. Dimmick, *Vice-Chairman*, RCA Victor Division, Camden, N.J.

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H. W. Bauman
R. J. Beaudry
A. C. Blaney
D. J. Bloomberg
F. E. Cahill, Jr.
E. W. D'Arcy
R. J. Engler
R. M. Fraser
J. G. Frayne
L. D. Grignon
Robert Herr
J. K. Hilliard
L. B. Isaac
E. W. Kellogg
J. P. Livadary
K. M. MacIlvain
W. C. Miller
G. C. Misener
Otto Sandvik
G. E. Sawyer
R. R. Scoville
W. L. Thayer
M. G. Townsley
R. T. Van Niman
D. R. White

STANDARDS. *To survey constantly all engineering phases of motion picture production, distribution, and exhibition, to make recommendations and prepare specifications that may become proposals for American Standards. This Committee should follow carefully the work of all other committees on engineering and may request any committee to investigate and prepare a report on the phase of motion picture engineering to which it is assigned.* (*File 70*)

F. E. Carlson, *Chairman*, General Electric Company, Nela Park, Cleveland 12, Ohio

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TELEVISION FILM EQUIPMENT (JOINT RTMA-SMPTE COMMITTEE.) *To make recommendations and prepare specifications on all phases of film equipment as used in the television broadcast stations.* (*File 75*)

F. N. Gillette, *RTMA*, *Chairman*, General Precision Laboratory, 63 Bedford Road, Pleasantville, N.Y.

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TELEVISION STUDIO LIGHTING. *To make recommendations and prepare specifications on all phases of lighting employed in television studios.* (*File 85*)

Richard Blount, *Chairman*, General Electric Co., Nela Park, Cleveland 12, Ohio

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D. D. Cavelli
H. M. Gurin
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Adrian Terlouw
Malcolm Waring
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TEST FILM QUALITY. *To develop and keep up to date all test film specifications, and to supervise, inspect and approve methods of production and quality control of all test films sold by the Society.* (*File 95*)

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R. M. Corbin
Russell Drew
W. F. Kelley
J. A. Maurer
Joseph Spray
J. G. Stott
M. G. Townsley

THEATER TELEVISION. *To make recommendations and prepare specifications for the construction, installation, operation, maintenance, and servicing of equipment for projecting television pictures in the motion picture theater, as well as projection-room arrangements necessary for such equipment, and such picture-dimensional and screen-characteristic matters as may be involved in high-quality theater-television presentations.* (*File 90*)

G. L. Beers, *Chairman*, RCA Victor Div., Camden, N. J.

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James Frank, Jr.
R. L. Garman
E. P. Genock
A. N. Goldsmith
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L. L. Ryder
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Ed Schmidt
A. G. Smith
E. I. Sponable
J. E. Volkmann

THEATER ENGINEERING. *To make recommendations and prepare specifications of engineering methods and equipment of motion picture theaters in relation to their contribution to the physical comfort and safety of patrons, so far as can be enhanced by correct theater design, construction, and operation of equipment.* (*File 100*)

J. W. Servies, *Chairman*, National Theatre Supply, 92 Gold St., New York 7.

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A Comprehensive Proposal for a Closed-Loop Theater Television System

By R. L. Garman and R. W. Lee

Theater television offers tremendous possibilities to the motion picture industry as a new form of entertainment, but requires picture quality which measures up to the high standards of 35-mm motion picture practice. A totally new system is proposed which can produce the required picture quality. It differs from the home television system in several important respects, such as a higher number of scanning lines, a lower frame frequency, and greater video bandwidth. New electronic bandwidth-compression techniques may enable transmission of the improved picture over presently available relay facilities. Detailed discussion of the new standards and techniques points out advantages and possible disadvantages of this approach.

Sooner or later the motion picture industry must be prepared to develop its own television production facilities. Television techniques, because of their inherent convenience and artistic potential, appeal to producer and director on first inspection. They allow continuous program monitoring and immediate control of picture quality. Special artistic effects are readily created. Individual camera outputs can be combined at will to produce material with greater entertainment value than can be seen from any point on the studio floor. The television broadcaster has shown how valuable these techniques can be in creation of program material. The theater, however, must be prepared to offer considerably better picture and program material than is available to the home television viewer. The director, given adequate tools with which to work, can be relied on to produce program material of the necessary quality, but responsibility for picture quality rests with the equipment designer. At the very least, picture quality should be on a comparable level with the present high standards of 35-mm film productions.

The proposed GPL Theater Television System is the result of a basic study of the technical and artistic goals which can be attained in closed-loop theater presentation of television program material. This study was conducted with the firm conviction that television techniques available today, or on the immediate horizon, are capable of producing the quality of picture and program necessary for theater television.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by R. L. Garman and R. W. Lee, General Precision Laboratory, Inc., Pleasantville, N.Y.

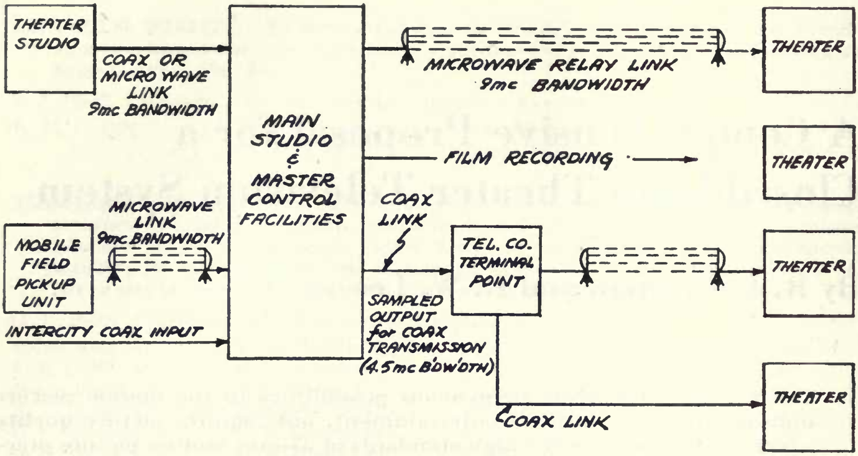

Fig. 1. Over-all system layout for closed-loop theater television.

It is realized that the practical system must represent a realistic compromise between quality on the one hand and cost and complexity on the other, and should be capable of conversion to color at a later date without wholesale obsolescence of equipment.

System Plan

Figure 1 illustrates, schematically, the broad outline of the proposed system. The master control facility is located in the building which houses the main studios. Remote program sources are linked to this central station by microwave relay. Programs are routed to theaters through microwave links (owned or leased) or via coaxial lines from a common carrier system. It will be noted that studio facilities for creation of live shows are provided. Main studio facilities include video recording equipment. This equipment provides a permanent film record of live shows so that film is available for later presentation, or for distribution to theaters not served by television transmission. Program control at the theater allows switching from central station program material to television broadcasts of special interest when desired. Program control at the studio allows selection of remote program material from a mobile pickup unit, the theater studio, or a syndicated program source other than the studio. Such syndicated program sources may be a logical future development.

35-Mm Motion Picture Quality

Complete specification of the quality of an imaging system requires detailed evaluation of the resolution, signal-to-noise ratio, contrast and transfer characteristics which can be realized. Fortunately, an analysis based upon resolution considerations alone can give considerable information. Such an analysis is not superficial, for, in general, the transfer characteristic, contrast and signal-to-noise ratio can be made nearly equivalent in film and television systems.

Schade,[1] in his very complete treatment of resolution factors, concludes that there is little difference in the inherent resolution capability of the 35-mm film system and an optimum 525-line 4.5-mc television system. The arguments are too lengthy to reproduce here in detail. Briefly, though, the analysis proceeds on the assumption that the resolution capability of any imaging system is the result of cascading

the resolution capabilities of a number of component parts and processes. In the film system, the cascaded components which enter the analysis are: (1) the camera lens, (2) the negative film, (3) the copying (positive) film and (4) the projection lens. In the television system, the components are: (1) the camera lens, (2) the camera tube, (3) the electrical channel, (4) the raster, (5) the kinescope and (6) the projection optics.

Schade's figures for the performance of component parts of system cannot be challenged, but his conclusion in regard to system operation is apparently based on a comparison between an *average* 35-mm film system and a *highly idealized* television system. Inspection of the material shows that it assumes: (1) the use of an experimental image orthicon with a 4½-in. diameter, (2) an experimental kinescope with a limiting resolution of 3000 lines and (3) ideal amplitude and phase correction in the electrical channel. Furthermore, the comparative ratings are based on the resolution obtainable at a point a few degrees off the axis of the system. The television and film processes are both charged with off-axis defects in the optical lenses. Off-axis defects in the electron lenses should be charged against the television system, but are not. Finally, a direct-projection theater television system includes a large-screen projection lens (probably of the Schmidt type) which is a significant limitation on resolution, while the comparative ratings are based on the quality obtainable with direct-view tubes.

One further consideration is important as affecting picture quality on a large screen. A television picture possesses line structure, and should be viewed at a distance large enough so that the eye integrates the line structure into a "flat" (continuous) field. With a picture containing 500 "active" lines, the viewing ratio (ratio of viewing distance to picture height) should be at least 4. In motion picture theaters, however, the viewing ratio varies from a minimum of about 1 to a maximum of perhaps 10. From this point of view, a 525-line television picture with a projected height of 15 ft will be of doubtful quality to anyone closer than 50 or 60 ft. Nearly 1000 (actually 975) scanning lines are required for a "flat" field at a viewing ratio of 2, 650 lines at a ratio of 3, and so on. Some improvement must be realized in this direction.

For these reasons, we conclude that the standard 525-line system cannot provide, on a large screen, picture quality equivalent to that of 35-mm film. Furthermore, because of the line structure, we believe that a 525-line system, even with increased horizontal resolution, is not satisfactory for theater television because it does not afford a reasonably flat field at viewing ratios less than 4. A higher line number is imperative for large-screen theater television.

Proposed Standards

As a result of a detailed study of all the factors involved, we are led to recommend the following standards:

Primary Standards

Frame frequency....	24 c
No. of lines per frame	675 double-interlaced
Line frequency......	16,200 c
Video bandwidth....	9 mc

Secondary standards

Vertical retrace time	5% of one field
Horizontal retrace time	20% of one line

Performance specifications

Effective signal-to-noise ratio (peak signal)/(rms noise).........	45 db minimum
Large-area contrast...	50:1 minimum
Detail contrast.......	20:1 minimum
Over-all transfer characteristic......	$E_i = E_0^n$, with $n \simeq 1.6$

Frame Frequency

The frame frequency of 24 c is proposed for two main reasons: (1) con-

servation of bandwidth and (2) compatibility with existing motion picture standards.

The proposed increase in line frequency for greater resolution necessitates a greater bandwidth, which is partially offset by reduction in frame frequency from 30 to 24 c. No greater economy is attempted because a frame rate appreciably less than 24 c would pose serious flicker problems. Even at 24-c frame rate, the 48-c large-area flicker frequency obtained in a double interlaced scanning system is just about the critical flicker frequency for the human eye, at a brightness level of 5 to 10 ft-L, with the phosphor decay characteristic of present-day picture tubes. There is reason to believe that phosphors with a longer decay characteristic and a very high efficiency will be available in the near future. Although it is probable that a 48-c field frequency is adequate to eliminate large-area flicker with presently available tubes, these new phosphors can be expected to eliminate the problem entirely.* With the aid of the new phosphors, interline flicker should be no trouble. Even with present phosphors the situation should be no worse, at a given viewing distance, than with the 525-line, 30 frame/sec system because of the larger number of scanning lines in the proposed system.

Pickup from film is somewhat simplified if the film and TV frame frequencies are equal; and is very much simplified in the case of flying-spot-scanner-continuous-motion-projector combinations.[2] This type of film equipment cannot be ignored, as it is now in use in France and England, where it produces exceptionally fine signals.

It may be noted that video recording at 24-c frame frequency poses different problems from those encountered in standard television at 30 c. The recording camera, if an intermittent type, must have a sufficiently fast pulldown mechanism to operate within the vertical retrace time. On the other hand, recording cameras of the continuous motion type are much simpler at 24 c than at 30 c.

The problem of satisfactorily fast pulldown mechanisms for intermittent cameras and projectors is not insurmountable. Simple extrapolations of conventional design in currently available mechanical intermittent mechanisms pull down film in approximately 15 degrees of shutter rotation. Completely new approaches to the problem now give promise of achieving pulldown in less than the minimum vertical retrace standard set by the FCC.

The most important reason for adoption of 24-c frame frequency is that the video bandwidth required for a given horizontal resolution at a given number of scanning lines is only 80% of that required at a frame frequency of 30 c. Taking into consideration all of the above, we feel that the adoption of a 24-c frame frequency is clearly justified.

Line Frequency

It is highly desirable that the line frequency be kept fairly close to the present 15.75 kc so that the same horizontal sweep circuits, sync generators and similar elements may serve for both theater and home television standards. Once the frame frequency has been chosen, selection of a line frequency resolves into a choice of the number of scanning lines. In this case, the number of scanning lines should be such that, at 24 frames/sec, the resulting line frequency is within a few per cent of 15.75 kc. For a double-interlaced system, the number must be odd. Then, in order that sync generators using frequency dividers may be adapted to the system, the number should be a product of small prime factors. The number 675 seems a logical choice. Its prime factors of 3 and 5 are easily implemented in a divider

* Note added at press time: A recent publication[7] from the Philips Laboratories at Eindhoven provides the latest available information on this subject.

chain. It yields a line frequency of 16.2 kc, which is only 3% higher than the present standard. The next highest such number is 729, which would call for a line frequency of 17.4 kc, or about 10% higher than the standard figure. A 5% vertical retrace, with 675 lines per frame, would leave 640 active scanning lines in the picture. Hence, a flat field would be preserved for viewing ratios as small as 3.

Accordingly, we propose a scanning line number of 675 lines/frame, interlaced two-to-one, and a line frequency of 16,200 c. This is sufficiently close to the home television standard that there need be no difficulty in operating studio equipment and receivers interchangeably between the two standards. Furthermore, appreciably higher resolution and an appreciably smaller minimum viewing distance are afforded by the 640 active scanning lines.

Bandwidth

There are very cogent technical reasons for restricting bandwidth. The video bandwidth limitation of transmission systems in the ultra-high-frequency and microwave region is a primary consideration. An even more pertinent restriction arises from the characteristics of the human eye. As long as the horizontal and vertical resolutions are approximately equal, the eye accepts an increase in either one as a contribution to the over-all impression of sharpness. But, as Baldwin[3] points out, the subjective impression of sharpness increases more and more slowly with respect to objective factors as the image becomes sharper.

Schade's concept[1] of an "equivalent optical aperture" provides a useful tool for correlating image resolution and bandwidth requirements when the number of active scanning lines is known. In keeping with this concept, degradation of detail signals is considered to be an effect caused by integration of signal flux within an aperture, and can be defined in terms of that aperture when the size and flux distribution of the aperture are known. The aperture may be either real or fictitious. Thus, while loss of resolution may be due to either a wide scanning aperture in an image dissector tube or a narrow frequency channel, the end effect is similar and may be evaluated in terms of a common variable. Each stage in a multistage process can, in general, be considered in terms of its particular equivalent optical aperture, and the cumulative effect of cascaded apertures can be evaluated by the rule of squared sums. The performance of a practical imaging device is specified numerically in terms of a "flux response factor," $\gamma\Delta\bar{\psi}$, which, being a measure of the effect of the aperture on square-wave response, is roughly analogous to the power vs. frequency-response characteristic of an amplifier.

The raster and the frequency channel can be considered as cascaded apertures. Schade's method and notation are applicable and will be used. For a raster with N_v active scanning lines, the flux response factor is 0.5 at a line number $\sqrt{2}N_v$. The equivalent optical aperture of an ideal frequency channel accommodating N_H horizontal lines has a flux response factor of 0.5 at a horizontal line number $1.75\sqrt{2}\,N_H$, when N_H is greater than 500. The cascaded value of these two apertures yields the theoretical limiting value of the equivalent aperture for which, in an ideal system with perfect components, the flux response factor is 0.5. The performance of the equivalent optical aperture of the 675-line, 24-frame system and frequency channel can be stated in terms of the line number, $\overline{N}_{0.5}$, at which the flux response factor is 0.5. The aperture defined by $\overline{N}_{0.5}$ is then the theoretical limit for an ideal system with perfect components. This value can be expressed as:

$$\overline{N}_{0.5} = \frac{1}{\sqrt{\frac{1}{2N_v^2} + \frac{1}{6.12N_H^2}}}$$

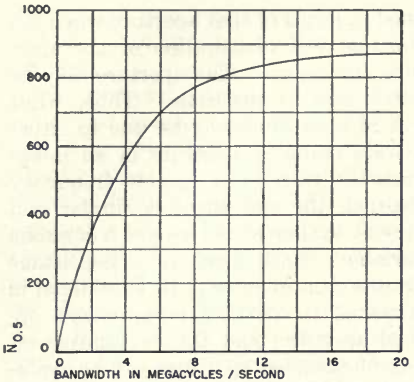

Fig. 2. Theoretical resolution capability determined by the equivalent optical aperture of an ideal 675-line, 24-frames/sec television system, as a function of the bandwidth.

This expression points up immediately the fact that the limiting value of resolution is $\sqrt{2}N_v$, even for infinite bandwidth (infinite N_H). Hence it is not economical to increase horizontal resolution indefinitely. A plot of $\overline{N}_{0.5}$ against bandwidth is given in Fig. 2, for N_v = 640, and 24 frames/sec, assuming the blanking times specified in the proposed standard. The figure of 9 mc which is proposed for the bandwidth yields a value reasonably close to the theoretical limit (800 lines, as opposed to 900). Increasing the bandwidth beyond 9 mc would not produce an appreciable increase in sharpness, particularly when one considers the further limitations due to components such as the camera tube and projection kinescope. However, the theoretical limit of the system is high enough so that the frequency channel and scanning raster chosen will not limit the performance when improved tubes are available.

The proposed system includes provision for dot interlace. This technique may enable reduction of the video transmission bandwidth to one-half that of the video bandwidth of the system, plus the width of the guard-bands and audio channel. For areas not equipped with transmission facilities providing the full bandwidth, it may be possible to use 4 or 5 mc relay equipment and coaxial facilities, both of which are now available, to transmit a picture with an 8 or 9 mc video bandwidth as an interim measure.

Secondary Standards

Little comment is required on the retrace times specified. The vertical retrace time is chosen with the idea of realizing the maximum practical number of active scanning lines without increasing unduly the requirements on intermittent film mechanisms which might be used in both ordinary and theater television studios. The horizontal retrace time is approximately the same as in home television, which means that horizontal deflection components and circuits can operate on either standard.

Synchronizing Waveform

A synchronizing wave-form standard has not yet been formulated in detail. The equipment in the theater must be designed to accept standard 525-line, 30-frame/sec signals off the air. This places no limitation on the ability of the equipment to take full advantage of the resolution afforded by a 675-line, 24-frame/sec, 9-mc signal. (A compatible standard seems to be quite simple in concept.)

Performance Specifications

The performance requirements have been deliberately made more stringent than those met by presently available systems. They thus serve as goals for further development.

The signal-to-noise ratio figure is definitely obtainable, if one is able to pay the cost, which is primarily the cost of studio lighting and of transmission power. The threshold of noise visibility on television pictures has been investigated by several groups.[1,4] It has been shown that the eye acts as a "low-

pass filter" to brightness fluctuations in the television image. Peaked-channel noise in which high-frequency components are predominant is therefore less visible than flat-channel noise, for a given measured ratio of peak signal power to noise power. This is the reason for specifying a 45-db *effective* signal-to-noise ratio, which means "equivalent to a 45-db signal-to-noise ratio with flat-channel noise." To achieve this ratio, the effective signal-to-noise ratio of the studio output signal and of the transmission channel (including the receiver, if one is used) must each be at least 48 db. The over-all effective ratio of 45 db may be compared with Schade's[1] observed threshold values of 50 to 55 db, and present optimum home television performance of 30 to 35 db, set by the equivalent signal-to-noise ratio obtainable with the image orthicon.

The contrast obtainable in television systems at present is not completely satisfactory, even for home entertainment, much less for theater use. This limitation is due almost entirely to the cathode-ray tubes currently employed, but research in this field shows that some improvement is possible in new tubes currently under development.

There is at present a vast confusion (or, more accurately, a lack of standards) on the subject of the slope of the over-all transfer characteristic (equivalent to "gamma" in the film process) for television. Long experience in the motion picture entertainment field has proved that, for best audience entertainment value, the over-all gamma of that process should be between 1.6 and 1.7. Theater television presents the same audience situation as for 35-mm motion pictures, and we have adopted the same criterion; that is, the relation between image-point illumination on the theater screen and object-point brightness in the original scene should closely approximate a power law with an exponent of 1.6 to 1.7. Furthermore, the studio output signal should follow a standard characteristic, which is approximately a seven-tenths-power law, to correct the picture tube characteristic to this value. In order to arrive at this standard characteristic, for signals from varied sources within the studio, variable-power-law amplifiers are required.

Choice of Components

The course of equipment development and system design raises fundamental questions regarding components to be employed. In particular, the type of television camera tube and the film size for recording and reproduction, whether 35-mm or 16-mm, must be decided. These two components dictate the characteristics and detailed design of a large part of the accessory equipment and also define the extent to which the stated performance specifications can be met. It will be well to consider these components at this point in the discussion.

Camera Tubes

The pertinent characteristics of the camera tube are:

(a) Shape of the transfer characteristic (plot of current output vs. light input);

(b) Signal-to-noise ratio as a function of scene illumination and lens stop; and

(c) Resolution.

Image tube sensitivity is commonly specified by a tube manufacturer in terms of the highlight illumination required on the photocathode, or in terms of the scene brightness normally used. However, the absolute sensitivity of any imaging system is measured by the scene brightness only when the angular field, depth of field and signal-to-noise ratio are known. Further, a comparison between highlight photocathode illumination figures is only possible if the photocathode areas are equal. But, when the angle of field, depth of field and scene brightness are specified, the *total image light flux* is fixed. The im-

portance of this figure has been emphasized by Rose[5] and others. A comparison between tubes may therefore be based on the total image light flux for a given signal-to-noise ratio.

The signal-to-noise ratio affects the quality of the picture viewed by the audience. One might expect that the signal-to-noise ratio could be neglected in a relative rating of camera tubes, but the point is that there is an important difference in the visibility of the noise spectrum associated with different types of tubes. The noise associated with tubes which contain a signal multiplier is flat-channel noise, or "white" noise. The noise associated with tubes which do not contain a signal multiplier is the noise at the amplifier input, which at the output is peaked-channel noise, with the high-frequency components emphasized relative to the lows. Since the high-frequency components are enhanced in peaked-channel noise, the filter effect of the eye is greater with "peaked" than with "flat" channels. Quantitatively, the following figures may be stated:[1] For the same measured ratio of signal voltage to noise voltage in a 4-mc channel, the visibility of "peaked-channel" noise is about one-third that of "flat-channel" noise. In a 9-mc channel, the visibility ratio is about one-sixth.

One further factor is pertinent to a comparison between camera tubes. Absolute sensitivities must be considered in terms of the studio light level required for a given lens stop. The assumption that camera lenses are set at $f/8$ will be convenient for calculating the illumination required. This setting provides very excellent depth of field and seems to be a conservative figure.

Any consideration of camera tubes for use in television must start with the image orthicon. The phenomenal sensitivity of this tube has made it completely standard in the American telecasting industry. The studio illumination required by the 5820 tube at a lens speed of $f/8$ is less than 100 ft-c.

Unfortunately, the maximum obtainable signal-to-noise ratio is not high. For commercially available tubes in a 4.5-mc channel, the figure quoted by the manufacturer[6] is 70:1 for the narrow-spaced variety (5655, 5826), and 35:1 for the wide-spaced (2P23, 5820). The current output saturates sharply at a certain maximum value of illumination. If the illumination on a narrow-spaced tube such as the 5826 is increased above this value, a picture is still obtained because of redistribution effects, but it is a picture of doubtful quality. Essentially, the design of the image orthicon has purchased extreme sensitivity by the use of: (1) a relatively low-capacity target and (2) low-velocity beam scanning, which limits the permissible element voltage. Both of these factors limit the stored charge and signal-to-noise ratio. Because a signal multiplier is used, the noise in the output is the combination of scanning beam noise and fluctuations in the stored charge, and is "flat-channel" noise. Hence, for a 9-mc channel, the average "effective" signal-to-noise ratio which can be guaranteed with commercially available tubes is 50:1, or 34 db, as against the 48 db required by the system specification.

There are other drawbacks to the use of the image orthicon. Spurious signals due to redistribution effects (black edges around highlights, the lack of cleanness in large black areas) are objectionable, and little can be done about them in the way of shading. The restricted range of the tube requires caution in lighting and compels the use of rather flat illumination in studio scenes. The limiting resolution obtainable in the standard-size tube is about 600 lines per picture height. Since the transfer characteristic is approximately linear, correction of the characteristic (black expansion, white compression) is prob-

ably required, with a resultant expansion of the noise in the blacks. Caution is required in the use of the tube to prevent picture "sticking" or "burn-in." Taking everything into consideration, with particular attention to the signal-to-noise ratio and resolution, it has been impossible to conclude that the sensitivity of the tube outweighs its other drawbacks, where the goal is high quality and high resolution.

Granting that there is no other tube which approaches the image orthicon in sensitivity, the question may be asked: what is the maximum tolerable light level in the studio? It can be assumed that the tolerable levels are those set by present motion picture film studio practice. Hence, the requirement which the camera tube should satisfy is that when operating at a light level of 500 ft-c, it must yield a satisfactory signal-to-noise ratio at a lens stop which yields the same depth of field as an image orthicon with the lens set at $f/8$.

If one disregards the iconoscope as being of unusably low sensitivity, the alternatives left are the orthicon and the image iconoscope. Tubes of the orthicon type suffer from instability at high light levels, and "smearing" or "streaking" for rapidly moving objects in the field of view. An image iconoscope, the Photicon, manufactured by Pye, Ltd., of Cambridge, England, seems to be best suited to the requirements and is our present choice.

The Photicon has the required sensitivity. Although higher light levels are required than with the image orthicon, an effective signal-to-noise ratio which meets the system specification of 48 db can be achieved. Since the Photicon does not use a signal multiplier, the noise level is set by the amplifier input circuit and the noise currents in the first stage, and is therefore "peaked-channel" noise. The visible effect of this type of noise is only one-sixth as great, for a 9-mc channel, as the visible effect of "flat-channel" noise. Hence, the specification of an "effective" 48-db signal-to-noise ratio requires a measured ratio of peak-signal-to-rms-noise in the Photicon channel of only 32 db. This ratio can be obtained at a lens stop of $f/5.6$ with less than 500 ft-c incident illumination on the scene. In considering this figure, it should be remembered that the depth of field obtained with a Photicon at $f/5.6$ is the same as that obtained with an image orthicon at $f/8$, because the size of the photosensitive area in the Photicon is smaller by about 40%.

The Photicon offers a number of other advantages. There is no problem of picture sticking. There is no saturation, but only a gradual white compression which is actually an advantage, since it obviates the necessity for a certain type of "gamma" correction which is required with the image orthicon, and eliminates the requirement for flat lighting. The picture is quite clean, requiring less shading than the iconoscope, and being free from the background signal, black rings around highlights and difficulties with large-area blacks encountered with the image orthicon. The resolution is not limited by mesh screens, and may be pushed as high as 1200 to 1500 lines.

For outside or mobile pickup, the image orthicon must still be used, for it is the only tube which has the required sensitivity.

Film Size

The extent to which film may be used in programming for a theater television system is a highly debatable point. Film is currently a major source of program material for home television. There are a number of good reasons why there should be less dependence on film in theater television. It is almost certain, however, that some film programs will be used, and hence film material must not be ignored.

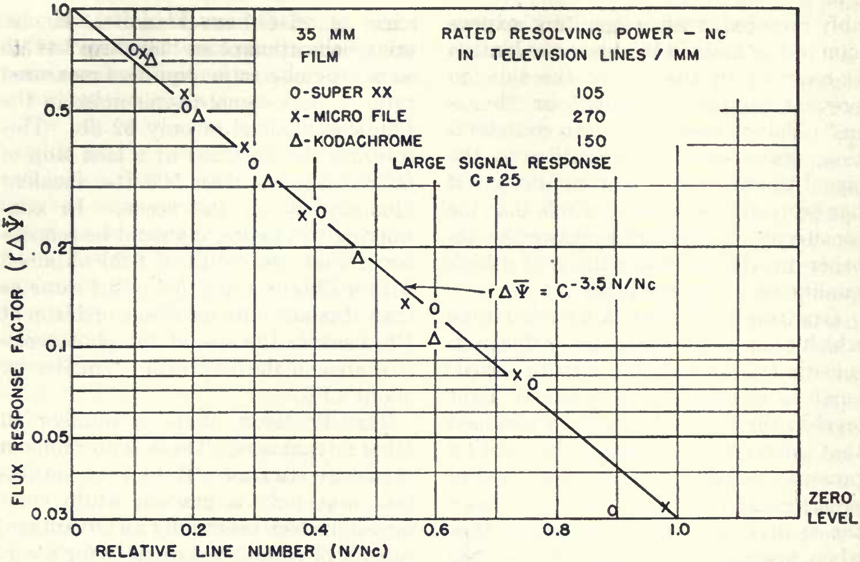

Fig. 3. General aperture response characteristics of photographic film for large signals (*Courtesy RCA*).

The size of film stock to be used, whether 35-mm or 16-mm, depends on the resolution capability of film. Schade[1] has made quantitative measurements of the flux response factor for film stocks as well as for components of the television system. In the case of film, this measurement is made by a television scanning technique labeled a "television microphotometer." The flux response factor is 1.0 at very low line numbers, and decreases more or less uniformly to zero at N_c, the limiting resolution. The original curve is reproduced in Fig. 3. The limiting resolution for Super-XX negative film is about 100 (TV) lines/mm; for Microfile about 270 lines/mm. The flux response factor is 0.5 at 21 lines/mm for Super-XX and 55 lines/mm for Microfile.

A flux response factor of 0.5 would not represent a severe limitation on system resolution. However, a flux response factor of 0.25 is, in practice, about the minimum which could be tolerated for any one step in the process. This figure can be obtained in a Super-XX negative at a line number of 45 lines/mm. One copying process onto fine-grain positive film reduces this figure to 38 lines/mm. This is just tolerable if 35-mm film is employed, for the frame height of 15.7 mm gives a practical resolution of just 600 lines. Of course, the limiting resolution is well in excess of this figure, something like 1100 to 1200 lines in the 35-mm frame. Without hesitation, therefore, we have proceeded on the assumption that 35-mm film will be used. It is required in a high-quality system.

Conclusion

The foregoing proposal is intended to invite comment and criticism, particularly in regard to the objectives outlined and the means chosen to achieve them. It is believed that the performance goals are realistic and realizable. A complete system of the type proposed, if implemented today with components which are currently available, can achieve a fairly close approximation to the ultimate performance goals. New

developments can be incorporated as the art progresses, within the framework of the proposed standards.

References

1. O. H. Schade, "Electro-optical characteristics of television systems: Introduction," *RCA Rev.*, vol. 9, no. 1, pp. 5–13, Mar. 1948.
   "Part I — Characteristics of vision and visual systems," *ibid.*, pp. 13–37, Mar. 1948.
   "Part II — Electro-optical specifications for television systems," *ibid.*, no. 2, pp. 245–286, June 1948.
   "Part III — Electro-optical characteristics of camera systems," *ibid.*, no. 3, pp. 490–530, Sept. 1948.
   "Part IV — Correlation and evaluation of electro-optical characteristics of imaging systems," *ibid.*, no. 4, pp. 653–686, Dec. 1948.
2. R. L. Garman and R. W. Lee, "Image tubes and techniques in television film camera chains," *Jour. SMPTE*, vol. 56, pp. 52–64, Jan. 1951.
3. M. W. Baldwin, Jr., "The subjective sharpness of simulated television images," *Bell Sys. Tech. Jour.*, vol. 19, pp. 563–586, Oct. 1940.
4. P. Mertz, "Perception of television random noise," *Jour. SMPTE*, vol. 54, pp. 8–34, Jan. 1950.
5. A. Rose, "A unified approach to the performance of photographic film, television pickup tubes and the human eye," *Jour. SMPE*, vol. 47, pp. 273–293, Oct. 1946.
6. *RCA Tube Handbook.*
7. J. Haantjes and F. W. de Vrijer, "Flicker in television pictures," *Wireless Eng.*, vol. 28, pp. 40–42, Feb. 1951.

Discussion

Otto H. Schade: Having been quoted a number of times in the paper, I would like to make some remarks and point out differences in opinion on some of the statements made.

Mr. Lee mentioned that I failed to include the off-axis resolution loss in television tubes while taking it into account for optical lenses. A justification for doing this in the quoted evaluation of a particular television system is the fact that electrical focus modulation can be used (as I have done) to maintain a perfectly uniform focus over the picture area in both camera tubes and kinescopes. This is, of course, not feasible for optical lenses.

I would like, further, to make some comment on the proposed frame repetition rate. A rate of 24 television frames per second can, in my opinion, lead to complaints with regard to detail flicker and more noticeable failure of interlace which occurs at certain rates of vertical motion in the television picture. Most of you have probably seen this effect on good television receivers, where, at times, the scanning-line raster seems to contain only one-half the number of lines when the camera pans up or down at certain speeds. This apparent failure of interlace is not caused by a defect in the electrical timing system but is due to optical and geometric effects resulting from the time difference of partial rasters in an interlaced system. The defect increases with picture brightness (reduced storage of the eye), decreased persistence of the kinescope phosphor, with decreasing frame rate, a lower raster-line number, and it increases further with the resolution of the system. The reduced brightness of a large-screen theater projection and the somewhat longer persistence of projection-tube phosphors are, hence, an advantage reducing the effect at a frame frequency of 30 cycles, but these advantages are perhaps more than canceled by reducing the frame rate to 24 per second. I would, therefore, suggest that a decision with regard to the proposed decrease in frame rate should be made only after comparative demonstrations have been given.

A reduction of the suggested frequency channel of 9 mc to 4 or 5 mc by the use of horizontal dot interlace appears, offhand, very attractive. The dot interlacing process effecting an increase of resolution in the horizontal direction, however, is based on the same principle as the increase of vertical resolution (line number) by the normal line interlacing process, namely, that alternate picture elements or lines only are reproduced in sequence, the reproduction of intervening elements being delayed in time. The picture repetition cycle is thus increased by vertical interlacing to two vertical scanning periods containing two sets of horizontal

lines. The addition of horizontal dot interlace breaks up the horizontal lines into a series of dots with intervening empty spaces to be filled out in the following two fields, a complete picture thus requiring four fields. The frame frequency is, therefore, reduced to one-half (i.e., 12 or 15 cycles for a normal frame frequency of 24 or 30 cycles, respectively). The effects of flicker and interlacing failure mentioned above now occur also in the horizontal direction and are considerably more evident because of the lower repetition rate and the more frequent motion in the horizontal direction. I do not think that a decision on horizontal dot interlace could be made solely on a theoretical basis considering a stationary pattern, unless extended to and substantiated by satisfactory demonstrations of moving subjects.

It should be mentioned that horizontal dot interlace for the purpose of gaining black-and-white picture resolution is very different from the dot interlace system used to add color information, because in the latter, dots are not omitted leaving blank spaces when scanning a line, but rather the color components of the kinescope light are changed at a corresponding rate.

I finally wish to make some comment on the performance of television tubes and, in particular, the image orthicon relative to other camera-tube types, as it seems to me that the figures quoted on image orthicons and camera tubes, in general, can lead to misconceptions and do not fairly evaluate and compare the true operating conditions and characteristics demanded of practical camera tubes. With regard to the resolution required of a theater television system, in general, which is to be equivalent to a 35-mm motion picture system, one can make the following simple analysis of component quality without putting a restriction on line numbers or frequency channel. From this analysis one can form a rough opinion how existing components and anything available so far in television system components compare with ultimate requirements. The one figure commonly known for the components of a motion picture system is their limiting resolution. Aside from the camera lens, which will be omitted because it is used in both cases, a good motion picture system uses Plus X negative film with a limiting resolution in the order of 1400 television lines (counting black and white lines) in the vertical frame dimension.

When mechanical errors in camera, printing and projection machines are neglected, the remaining elements are the fine-grain positive film with a limiting resolution of roughly 2800 lines and the 4-in. $f/2$ Super Cinephor projection lens which is 2400 lines on the same basis (2% response) according to a sample measured by myself. Comparing these motion picture components with corresponding television system components, a camera tube (replacing the negative film) having a resolution of 1400 lines, a kinescope (replacing the positive film) having a resolution of 2800 lines, and projection optics (replacing the Super Cinephor) with a resolution of 2400 lines would certainly give the same over-all result, provided the detail contrast decreases similarly as a function of line number toward the limiting resolution in respective components. This is approximately the case for the elements mentioned. Introducing now, in addition to these elements, a limited electrical frequency channel, it is obvious on an optical basis that the afore-mentioned components should resolve higher line numbers to maintain the same over-all detail contrast below the limiting resolution. It can be shown, however, that the limiting resolution itself is actually not very important in comparison with good detail contrast at lower line numbers. An increase of detail contrast can be obtained by providing a relative increase of amplification for the corresponding detail signals in the electrical system. This correction, termed aperture correction, is effective in the horizontal picture dimension but not in the vertical picture dimension. The use of a large scanning-line number in a given television channel reduces the horizontal resolution and results in a less effective correction of detail contrast than selection of a lower number of scanning lines which corresponds to a higher horizontal resolution and, at present, gives a better over-all result.

When resolution under normal operating conditions of a camera is evaluated, it is common knowledge that the sharp-

ness of the camera image can be quite inadequate when lacking depth of focus, even though the resolving power of lens, film or camera tube are excellent. For a given scene illumination and exposure time, the sensitivity of the camera tube becomes a controlling factor for the depth of field and degree of perspective which can be imaged sharply. The sensitivity of the image orthicon is fundamentally several times higher than that of the image iconoscope referred to by Mr. Lee. The image orthicon permits a smaller lens stop setting, a greater depth of focus and, therefore, actually a generally sharper image of scenes with good perspective even though the maximum resolution of the commercial image orthicon is not as high as the figure quoted for the image iconoscope. The figure for the latter, according to my measurements and experience, appears somewhat optimistic and is certainly varying considerably over the inclined image surface of that tube.

With regard to signal-to-noise ratios, R, obtinable with the image orthicon, I would like to mention that a ratio, $R = 75$, should not be considered as a limit, because as in all camera tubes the value R can be changed by changing the target capacitance. I have measured values of 135 on the type 5655 tube and as high as 180 on larger tubes with 4½-in. face plates, which, incidentally, have resolutions between 1500 and 2000 lines. A comparison of the flat-channel noise from an orthicon with the peaked-channel noise of an image iconoscope in a 9-mc channel made by Mr. Lee came out in favor of the image iconoscope.

Taking the quoted value, $R = 75$, for an image orthicon in a flat 4.5-mc channel, an increase to a 9-mc channel reduces the value to $R/\sqrt{2} = 53$. For an amplifier noise current of 0.0035 μa and the relatively high signal current of 0.14 μa from an image iconoscope, the ratio, $R = 40$, is obtained in a peaked 4.5-mc channel; which decreases to $R = 40/2^{3/2} = 14$ in a 9-mc peaked channel. For a theater system with a symmetric resolution of $N = 600$ lines, the relative visibility of peaked-to flat-channel noise is approximately 6 to 1 for a viewing distance of four times the picture height, as quoted from my paper, when including a kinescope with a 1000-line resolution limit which was found inadequate above and also by Mr. Lee. We have, thus, the value, $R = 53$, for the image orthicon as compared to an equivalent, $R = 84$, for the image iconoscope. For increased kinescope resolution, however, the equivalence factor decreases from 6 toward 3.33 and R decreases from 84 toward 46.7, which is then lower than the value for the above image orthicon as borne out by actual observations. The same change in favor of the above image orthicon takes place also when decreasing the viewing distance to two times the picture height and retaining the 1000-line resolution limit of the kinescope. The conditions for the British C.P.S. Emitron (an orthicon type) are a little worse according to published figures.

It was stated further that the transfer characteristic of the image orthicon is linear. This is a misconception arising from a test with a small spot of light in a dark background. Actually the operating characteristic of a properly exposed image orthicon has a gamma between 0.7 and 0.8, the value decreasing with exposure and depending on various other operating parameters.

Mr. Lee: It should be pointed out that the figures which have been quoted for image orthicon performance are simply those which are specified in the *RCA Tube Handbook* and the available literature. This paper is a technical proposal of a set of standards which we believe represent a reasonable compromise between cost and performance and allow for a reasonable raster and channel which leaves room for improvements in components, but which do not arbitrarily limit system performance. Since it is only a proposal, it represents, of course, a number of ideas which have not been completely tested.

We have tried focus modulation in camera tubes and viewing tubes with a certain amount of success. I agree that much better results are obtainable with the camera tube than with the viewing tube. I do not remember the exact numbers. We have never been able to agree with the conclusion that it is fair or feasible to say that the resolution of a television picture, taking into account both the camera tube and the viewing tube, is as good in the corners as it is in

the center. We simply don't have an answer as yet to the possible objection to the 24-cycle frame rate or the things which happen in the event of vertical motion. How much that objection can be compromised by care in programming I don't know. I have seen pictures on the BBC, for example, which operates on a 25-cycle frame rate, where vertical motion causes trouble. How serious an objection that is, I don't know, because first of all, we have not been able to make complete tests, and secondly, we don't know how much the objection can be vitiated by care in programming techniques.

Concerning the use of dot interlacing to conserve transmission band widths, the question is something to which we will not obtain the final answer until complete experimentation is possible. It may be, as was actually represented in the slide which showed the proposed over-all system in the first place, that a 9-mc channel will be required to relay a black-and-white picture from the studio to the theater. We don't know yet. I agree with Mr. Schade that the story, so far as dot interlace is concerned, is different in color and in black-and-white. Transmission of a good quality color television signal should be quite feasible in a 9-mc band width at 675 lines, and I see nothing fundamental in the standards proposed and equipment we are developing which will prevent us from using line interlace, dot interlace, frequency interlace or whatever other system may be proved satisfactory by large-scale experiment.

Leonhard Katz: Mr. Lee, I was wondering why, in your paper and in the committee reports which preceded it, there appeared to be no mention at all of the intermediate film projection system which is presently being used by Paramount and several large theaters. I think the system has been previously discussed and has a number of advantages. Can this system be used at all? There seems to be absolutely no consideration given to such a use. It is available now and does not use projection tubes. So, it might have some advantages.

Mr. Lee: There is certainly nothing in the standards which prevents the use of intermediate film equipment.

Mr. Katz: Has it been considered at all?

Mr. Lee: Yes. It has been considered. As a matter of fact, General Precision Laboratory has on sale now a 16-mm intermediate film system for use with a 30-frame, 525-line television system. Consistent with the remarks I have made on the resolution on film, 35-mm would certainly be required for a system of 675 lines and 9 mc. Consideration has been given to it. No final decision has been made. Direct projection has been brought up here because at present the projection tube represents a fairly serious limitation on resolution in the system. However, there is a very strong objection to the use of intermediate film if a good direct projection tube is realized. These objections are in terms of operating cost, particularly when 35-mm film is used in place of 16-mm, the necessity of having operators tend it, and so on.

Donald E. Hyndman: In answer to the part of the question in which you referred to the committee, I don't believe that we ignored or even compromised with either system. Actually, what we are now doing is studying distribution facilities which apply equally well to the film storage system and the instantaneous system. In other words, if it works for one, it should work for the other, obviously, and should be an advantage.

Quality of Color Reproduction

By David L. MacAdam

The evaluation of quality of color reproduction poses many complex problems. Optimum reproduction needs to be identified. Since it depends upon the limitations of the reproduction process, as well as upon human vision and judgment, optimum reproduction will probably have to be determined for each process separately. The program is to vary the production controls in systematic manners, measure the resulting color reproduction in the best way known (e.g., the ICI method at the present time), submit the reproductions to visual judgment, and study the judgment data in comparison with the measurements in order to find significant correlations. The growing experience of such studies of color photography is suggested as a guide. Preliminary estimates of optimum reproduction and of seriousness of deviations may be based tentatively on results of studies of noticeability of color differences and on fragmentary results of studies of color photography. These estimates can be improved as various parts of the program are carried out.

"*Complete theories do not fall from Heaven . . .*" **(Freud).**

When asked how he obtained such delicate flesh tones, in the nudes for which he is famous, Renoir is said to have replied, "I just keep painting and painting until I feel like pinching—then I know it's right." Color photography and color television are far from such perfection, but no better prescription for improvement can be written.

Judgment and measurement are indissoluble partners in the task of assessing quality of color rendering. Color can be measured, as can weight and height, but no formula can be trusted to distinguish pleasing from displeasing color, any more than a formula based on dimensions guarantees beauty of form. The principal value of measurements in such problems is that they permit something to be recorded about the occasion when satisfaction is experienced, or dissatisfaction expressed. The judgment, "I like that," is fundamental to all knowledge of what constitutes a good picture, but the knowledge is as evanescent as the picture if no measurements are made to record what the picture was, when it was approved. However, it is useless to make measurements blindly. The most revealing measurable characteristics of a picture, as of a beautiful form, can be discovered only by searching for whatever specifications are shared by all pleasing examples and more or less violated by less satisfactory ones.

Neither painters nor those in charge of color control in photography or television can hope to succeed by blind reliance on measurements. If a modern painter should venture to assert that

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he surpasses Renoir in the ability to render flesh tints, on the grounds that measurements prove his tints are closer to those of the living model, he would quite properly be dismissed with ridicule. Renoir's paintings do not, and probably never did, "match" the flesh of his models. This is not a criticism of Renoir, but an object lesson from which we should learn to investigate carefully before we rely upon "color-fidelity" measurements.

This article is concerned with only the evaluation of color rendering. It is not concerned with the dependence of color on other technical or economic considerations. Such considerations might be the dependence of color reproduction on the available frequency-band width, on the relative widths of the color-separation channels, or on fineness of picture detail, or the necessity of eliminating flicker and edge or registration defects. These factors are discussed at length by other authors. This article is not based on any acquaintance with television, but on experience in the application of color measurements to color photography.

This article can only outline the problem, and review the partial investigations that have been reported and are known to be in progress. Basically, the crucial questions are only asked, not answered. A program is suggested, modeled on one which seems to be productive in photography. No formula for the evaluation of the quality of reproduction is recommended. It is doubtful that any valid formula can be derived from the fragmentary and largely contradictory data now available concerning visual sensitivities and tolerances for color errors.

The Psychophysical Approach

There is nothing new in the suggestion that the quality of color in photography and television should be determined by visual observation and judgment. Nor is the idea of measuring the colors without precedent. The particular point of this discussion is that neither of these alone is adequate, but that a systematic combination offers the most promise.

The weakness of unaided judgment is shortness of memory. This is aggravated by the common tendency to jump to conclusions in order to aid memory. Without measurement there is no way of identifying, much less of remembering, relevant factors in the pictures judged or compared. Without written records, it is impossible to accumulate much experience.

The particular features of the design of picture-producing devices, and adjustments of the controls can, of course, be recorded. Although variations of these factors are convenient for sampling the enormous gamut of possible reproductions, these factors are not likely to be the most relevant measurable quantities for distinguishing good from poor rendering. The principles of color measurement, which will be briefly reviewed, are more likely than equipment design or controls to yield quantities which can be associated with the quality of color reproduction.

However, in themselves, color specifications lack any critical value. "Color fidelity," defined[1] as "the degree to which the television receiver reproduces the colors of the original scene," reveals a serious misconception of the purpose of both color television and color photography. This definition prejudges the facts, quite mistakenly according to present indications. Optimum reproduction can be identified only by asking a number of people to indicate their preference and relative ratings of a widely representative variety of color renderings, by measuring many colors in the pictures, and by studying the color specifications in comparison with the relative grades assigned to the pictures by the judges. The discrepancies between the colors of the preferred picture (the norm)

and those of the original scene may or may not be feasible to produce, but if such discrepancies are found, then "errors" of reproduction should be measured relative to the norm, rather than relative to the colors of the original.

Only after that norm is established can the question of the relative importance of various kinds of errors have any meaning. Such questions are important, and their answers are doubtless complex. They probably depend more seriously upon what the subject is, than upon its precise color in the original scene. Renoir's particular subject is not likely to be portrayed frequently in television or motion pictures, but human skin will probably be fairly high on the list of the most critical subjects.

Measurement of Color

In order to measure a quality, such as color, we must conceive it as depending on the values of one or more variable quantities, and our first step is to determine the number of variables which are necessary and sufficient to determine the quality of a color. No elaborate experiments are needed to decide that color can vary in three, and only three, independent ways. We can realize this by noting that color sensations can differ only in hue, saturation and brightness. If we adjust one color so as to produce the same hue, saturation and brightness as another, the two colors are indistinguishable.

For a very great variety of colors, such adjustment can be accomplished by varying the intensities of red, green and blue light combined in the same area, by simultaneous superposition or by juxtaposition in such fine patterns that the separate components cannot be distinguished, or by successive presentation at a sufficiently high rate so that the alternations of colors cannot be noticed. All hues and all brightnesses can be obtained in this manner. The only limitation is of saturation.

Very few, if any, pure colors from the spectrum can be matched with this scheme, and colors nearly as saturated as the spectrum are also unattainable. But practically all colors encountered in nature, art and industry can be matched. The range of saturation producible depends upon the particular red, green and blue chosen for the synthesis. The gamut depends somewhat on the hues of those components, but much more directly on their saturations. The greatest possible gamut would be obtained by using components as saturated as spectrally pure red, green and blue. Colors of even greater saturation than the spectrum can be imagined, and can even be experienced, fleetingly, for example, by viewing spectrum green immediately after prolonged viewing of a bright, saturated red. More important, the amounts of different sets of red, green and blue light necessary to match various colors are related by simple rules which can be extended to infer the amounts of physically impossible, supersaturated red, green and blue primaries, the mixture of which would match every obtainable color, including even those of the spectrum.[2,3,4] These rules have been applied to extensive experimental data on the amounts of ordinary red, green and blue components needed to match colors, and the results have been recommended by the International Commission on Illumination (ICI), and adopted by the American Standards Association as the basis for the measurement of color.

The principles of color measurement are shown in Fig. 1, where E represents the spectral distribution of energy incident upon a reflecting sample and R represents the spectral reflectance of the sample. The spectral distribution of the light reflected into the eyes of the observer is represented by the product curve, $R \times E$. If the spectral distribution of the light incident upon the eyes of the observer is measured directly, for instance, by spectroradiometry of

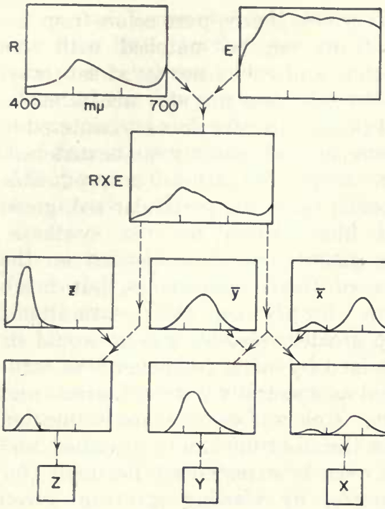

Fig. 1. Diagrammatic representation of principle of colorimetric specification.

the light from a television receiver, it can be used in place of the $R \times E$ curve. The standard ICI spectral-weighting functions, which correspond to normal human color vision, are shown by the curves, $\bar{x}$, $\bar{y}$, and $\bar{z}$. The areas under the curves which result from weighting $R \times E$ by the $\bar{x}$, $\bar{y}$, and $\bar{z}$ functions are the quantities, X, Y, Z, of the supersaturated ICI mixture components required to match the color of the sample. Routine methods of computation differ from this scheme only in details.[2,5,6]

In addition to including every color within their mixture gamut, the ICI components have the convenient property that the quantity, Y, specifies luminance (the photometric evaluation of brightness). The remaining two variables of color specify chromaticity, which is most conveniently represented by a point on a plane diagram. Such a diagram might be constructed by simply plotting Z vertically and X horizontally. If the ratios, Z/Y and X/Y, were plotted, however, all colors having the same relative energy distribution would be represented by a single point, regardless of their intensity, or luminance. This is a great convenience, since it enables us to study chromaticity independently of the intensity level. But the proportions of the resulting diagram are inconvenient. It is customary to plot, instead, the ratio, $X/(X + Y + Z)$, horizontally and the ratio, $Y/(X + Y + Z)$, vertically. The first ratio is abbreviated x and the second, y. The resulting diagram is shown in Fig. 2. The spade-shaped curve represents the colors of the spectrum, regardless of intensity. The straight line connecting its extremities represents the most saturated possible purples, from red at the right, through red-purples near the center to blue-purples and violet near the left corner. The curve tangent to the straight, long-wavelength (red) end of the spectrum locus and passing near the center of the diagram represents the colors of blackbody radiators* at various temperatures.

Since a blackbody at about 6500 K has nearly the same color as daylight, and household tungsten lamps operate at about 2800 K, any point near the corresponding segment of the blackbody locus may represent white, if the observer is adapted to the corresponding quality of illumination. This wide variation of the white criterion is an important fact. In one sense, it is fortunate because, for example, it permits the same motion picture films to be projected with tungsten lamps or with arc lamps of nearly daylight quality with very nearly equal satisfaction. Likewise, rather great variations of "balance" of color films and television pass unnoticed, provided that the picture controls the adaptation of the observer. However, if the surroundings are prominently illuminated,

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* A "blackbody" is a source which radiates energy in accordance with Planck's formula.

fluctuations of balance, and even the standard of white adopted for the production of the picture, can be very objectionable. This is presumably not important in theaters, because the illumination of the surround can be controlled. Greatest tolerance of the audience is obtained if the surrounding illumination is quite subdued, so that the picture, and its accidental variations of balance can control the adaptation.

The problem is much more difficult in the case of home television, because the ambient illumination may vary in quality from daylight to that from amber decorative luminaires, and the level of ambient illumination must be sufficient for easy movement and even for reading by uninterested members of the family. The choice of a standard for white that will be least objectionable under all likely conditions of adaptation is very difficult. This is not so critical in the case of "black-and-white" pic-

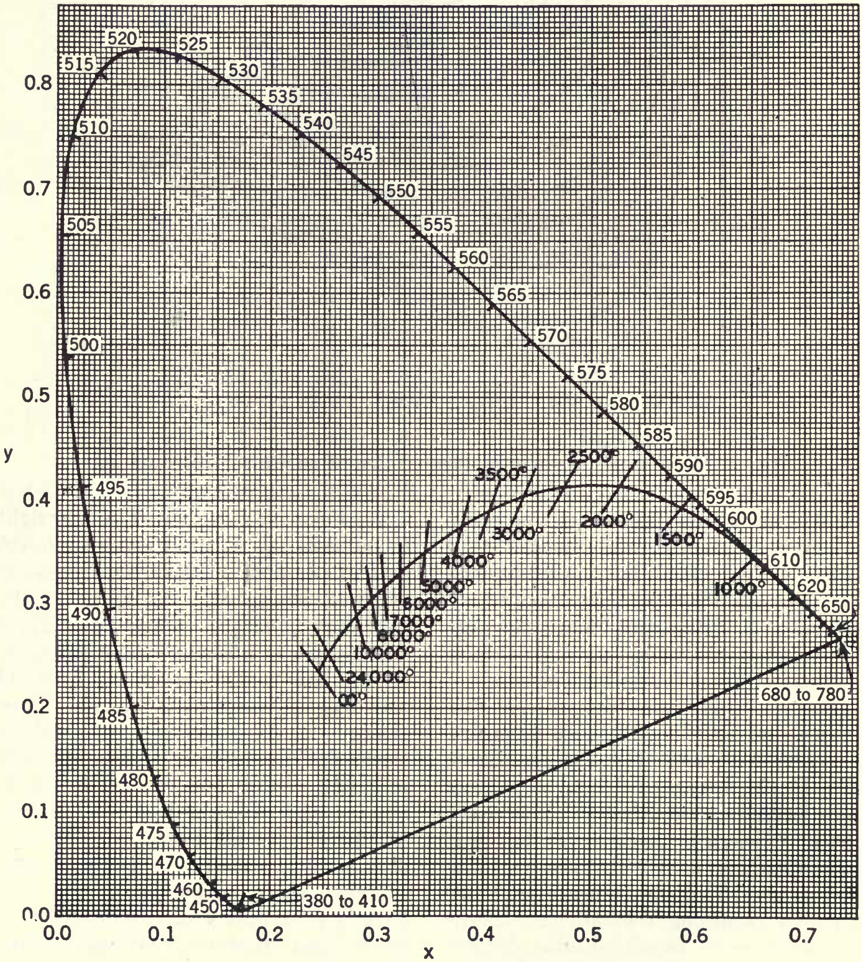

Fig. 2. Chromaticity diagram, showing locus of spectrum and locus of blackbody sources.

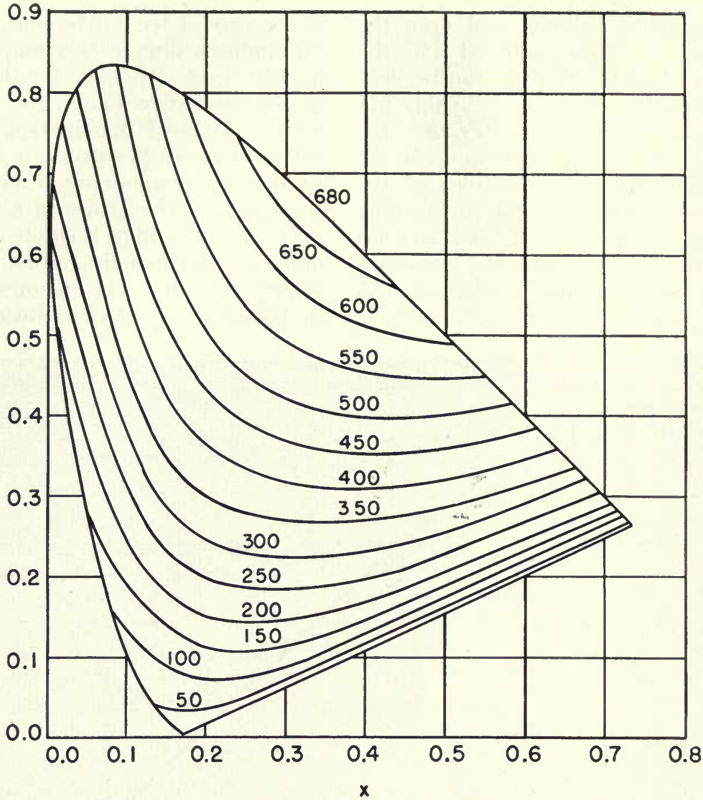

Fig. 3. Maximum luminous efficiencies of various chromaticities.

tures, for which observers are quite tolerant of "off-white" tints. It is much more critical for color pictures, because attention is then directed to color, and departures from the observer's ever-changing criterion of white distort his perceptions of all colors.

Figure 3 illustrates the general usefulness of the chromaticity diagram. On this is represented the maximum possible luminous efficiency of light of any desired chromaticity.[7] The maximum efficiency possible under any circumstances is 680 lumens per radiated watt. This maximum is obtained only by confining the radiated energy to a narrow band of wavelengths within a few millimicrons of 555 mμ. The maximum possible luminous efficiency for the chromaticity of daylight ($x = 0.31$, $y = 0.316$) is about 400 lumens per watt. This efficiency is not attained by natural daylight, nor by any existing lamps. It can be obtained only by use of a source whose spectrum is confined to two spectrum lines, at wavelengths 448 and 568.7 mμ. Such a source would be very objectionable as a practical illuminant, because it would seriously distort the normal colors of objects and the chromatic aberration of the eye would cause most objects illuminated with it to be seen surrounded by a violet haze. But the efficiency of that source is useful as a known goal that may be approached, but never exceeded, by a source having the chromaticity of daylight. Simi-

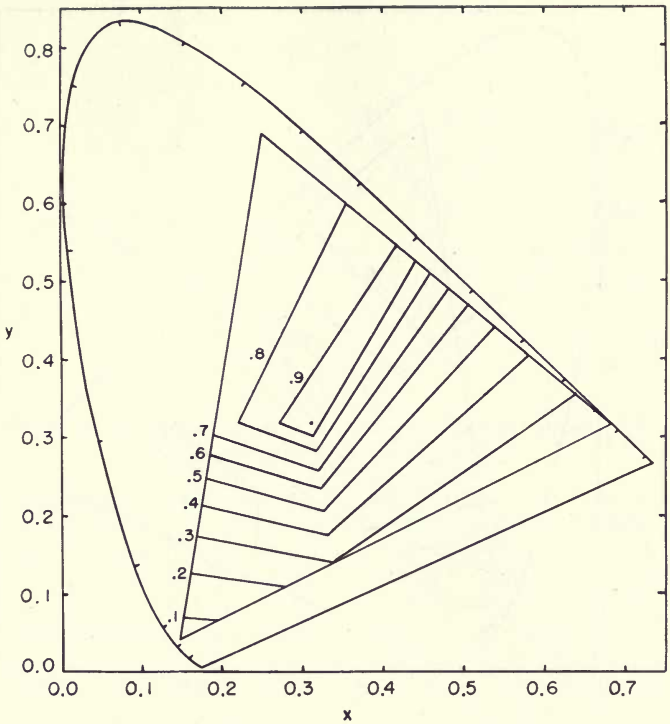

Fig. 4. Maximum luminances of various chromaticities producible by additive mixture of "C" primaries, based on assumption that maximum intensity of each is used to produce white.

larly, the efficiency indicated in Fig. 3 for any other chromaticity is a standard of comparison showing the amount of possible improvement in any practical case. It is interesting to note that, for almost all chromaticities, the maximum efficiency is obtained by adding 448 mμ to a second wavelength. This indicates, also, that the closer the blue primary approaches 448 mμ, the greater will be the luminous efficiencies of the chromaticities produced by additive combination of three primaries.

Similar diagrams showing the maximum possible luminous transmittances of filters having various chromaticities with daylight and tungsten light have been published.[8] From such data, Bingley[9] has computed the luminosities of two different sets of additive primaries required to reproduce the colors of the most efficient filters. Since the maximum efficiency has been closely approached only in the cases of a few yellow, orange and red filters, the requirements computed by Bingley are probably too severe.

The maximum possible luminous reflectances of colored materials having 2% minimum surface reflectance have been shown by Clarkson and Vickerstaff,[10] for tungsten lamp illumination. They also showed limits attainable with contemporary dyes. Probably those limits would be more realistic than the theoretical limits, for the determination of the maximum luminosity demands of additive primaries. However, the theoretical limits of luminous transmittance of filters, and of luminous reflectance

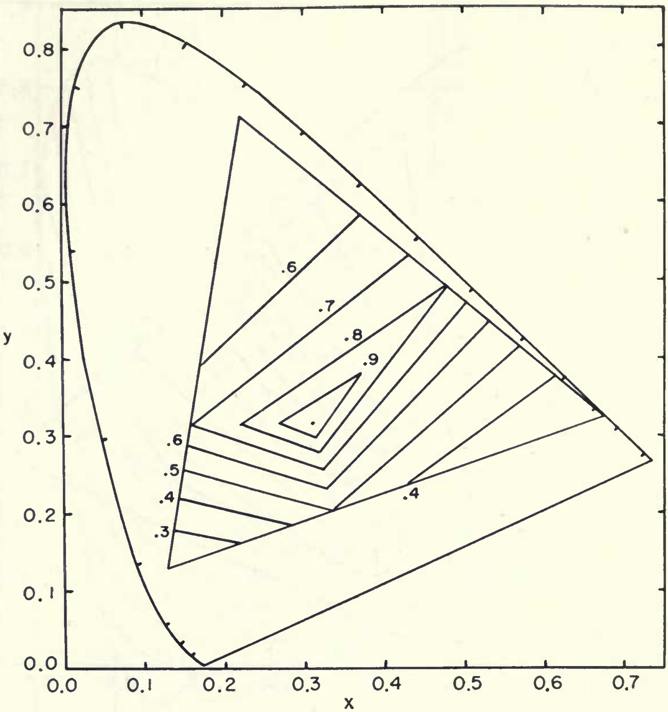

Fig. 5. Maximum luminances of various chromaticities producible by additive mixture of "A" primaries, based on same assumption as Fig. 4.

of colored materials having irreducible first-surface reflectance indicate the ultimate. The derivations on which they are based indicate the spectral characteristics that must be employed to attain the ultimate. Any other spectral characteristics necessarily produce lower luminous transmittance or luminous reflectance for any prescribed chromaticity.

The capabilities of a set of primaries may be shown in the manner indicated in Fig. 4, which, for some purposes, may be more informative than the diagrams that Bingley published. Figure 4 shows, for his "C" set of primaries, the maximum luminance with which any chromaticity can be produced, relative to white. It is assumed that the maximum usable intensity of each primary is used to produce white Figure 5 shows the corresponding diagram for the "A" set of primaries. Figure 6 presents a comparison of the chromaticity and luminance limits of these two sets of primaries. The lines indicating the luminosity limits in Figs. 4, and 5 may be regarded as contours of surfaces, below which are represented all colors producible by use of the corresponding set of primaries. This is illustrated in Fig. 6, which shows that the "ceiling" for the "C" primaries is above that for the "A" primaries in the green region (upper corner) and extends farther into the red, purple and blue regions (below), but that the ceiling for the "A" primaries extends slightly farther into the bluish-green region (to the left) and is higher in the

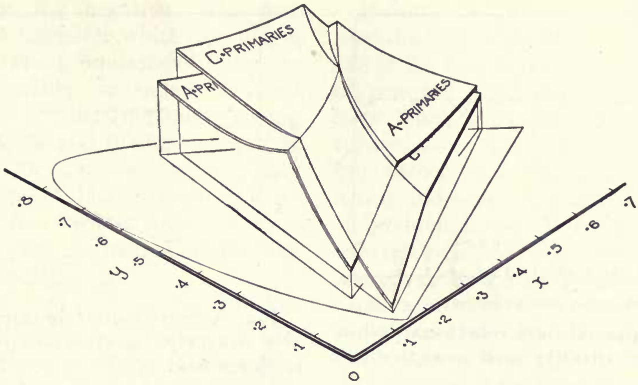

Fig. 6. Comparison of maximum luminances producible by use of primaries "A" and "C."

desaturated red region (right of center) than the ceiling for the "C" primaries. The ceilings are of nearly equal height (luminance) for desaturated blues (lower left central), but the ceiling for the "C" primaries extends to much greater saturations (down to the left). It may be interesting to note that the *Order* of the Federal Communications Commission, dated October 10, 1950, specified primaries which are very nearly the same as the "A" set.

The idea of a color space, suggested by this discussion, in which various luminances are represented by various heights above the chromaticity diagram, is very helpful in interpreting color measurements.

The luminance limits indicated by the contours in Figs. 4 and 5 are based on the assumption that white is the quality of the standard source, *C*, recommended by the ICI. As mentioned previously, this choice is arbitrary and might better be some other quality when the observers are not adapted to daylight, but the relations represented in Fig. 6 would not be altered seriously by any other reasonable choice of "white." The chromaticity gamuts indicated by the triangular boundaries in Figs. 4 and 5 are based on the assumption that a black of zero intensity can be realized and that any one of the primaries can be reduced to zero intensity, regardless of the intensities of the other primaries. The first assumption would not be applicable if any stray light from the surroundings is reflected from the screen, or if scattered light from neighboring portions of the image degrades the blacks. The second assumption would not be correct if there is any lower limit, other than zero, for the intensities of the primaries, or, in the case of a field-sequential system, if the persistence of the phosphor is so great that the image for one primary contributes appreciably to the luminance of the succeeding primary. In such cases, calculations of the kind used by Clarkson and Vickerstaff for dyed materials would be required to find the actual limits of chromaticity.

Returning now from this digression, concerning the general utility of the chromaticity diagram, we summarize the possibilities and limitations of color measurements. The physical factors of color can be measured by use of spectrophotometers and spectroradiometers. The psychophysical specifications of color can be determined by use of the principle illustrated in Fig. 1. But these specifications are, so far, devoid of critical sense on which judgments of picture quality might be

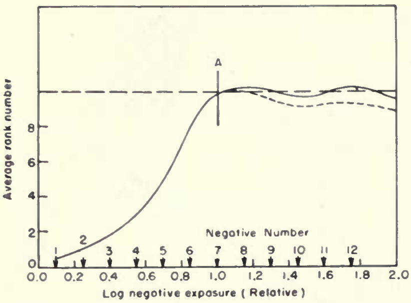

Fig. 7. Approximate relationship between print quality and negative exposure.

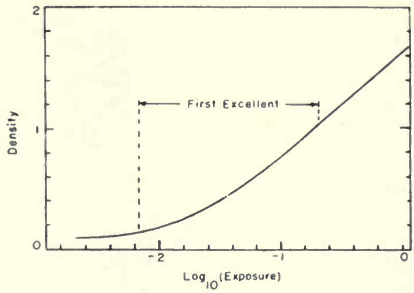

Fig. 8. Sensitometric curve of negative material, and exposures used in making first excellent print.

based. The problems remain, of discovering the proper "aim-points" for color rendering and of devising some way of evaluating discrepancies of actual color rendering from the optimum rendering.

Psychophysical Evaluation of Tone Rendering in Black-and-White Pictures

A great deal of work has been done and more is in progress, for the purpose of answering the above questions for color photography. The problems are not yet solved and few partial answers can be even suggested. It seems reasonable to expect, however, that a method of investigation which appears to be fruitful in color photography may also be useful in color television. That method is an extension of the method of investigating the quality of tone reproduction, which has been found successful in the case of black-and-white photography. The method and its potentialities can probably best be appreciated if that successful application of it is reviewed.[11]

Many variables influence the quality of black-and-white photographs. One which has been studied very thoroughly is the exposure given to the negative. Study of this case is important, because it provides a functional criterion for rating the speeds of various negative materials.

A certain scene was photographed repeatedly, using exposures varying by moderate steps, ranging from definite underexposure to definite overexposure.[12] All these negatives were made on the same kind of film and were developed identically. From each negative a series of prints was made, on several grades of paper. Each negative was printed on each grade of paper with definitely more and definitely less exposure than was desirable, and with several intermediate exposures.

The complete set of prints from each negative was submitted to a number of people, working separately. Each selected from the set for each negative the print he preferred. When the selections were compared, they were found to agree remarkably well. Finally, the judges were asked to arrange the best prints from all negatives of a single scene according to tone quality.

The results in one case are shown in Fig. 7, in which the average rank of each print is plotted as a function of the exposure of the negative from which it was made. The print judged poorest by each judge was given zero rank, and successive digits were awarded to successive prints, in the order of improved quality. Beyond about the seventh print, the average rank number fluctuates inconclusively about a constant value, indicating that no significant improvement results from greater

exposure of the negative. The first print, A, of those for which the judges could not report reproducibly any increase of quality, is called the first excellent print. Similar exposure series, print selections and quality judgments were made for many scenes of widely different types. The physical characteristics of the various negatives were measured, and compared with the judgment results.

The main result, the answer to the original question, is indicated in Fig. 8. This shows, in relation to the curve representing the density of the negative material as a function of exposure, the exposures used in making the first excellent print of one of the scenes. Other scenes, which had greater or less ratios of maximum to minimum luminance, required, of course, more or less of the exposure scale than indicated in Fig. 8. Study of the relation of the exposures used in producing the first excellent print in each case revealed that the minimum exposure should be that for which the slope of the D-vs.-log E curve is 30% of the average slope of the portion of the curve used for the average picture. This criterion was found to predict successfully, for average conditions, the least exposure required to obtain negatives from which excellent prints can be made. It has been made the basis for the American Standard method for determining photographic speed and speed number.[13] It was not derived from purely physical principles, nor could it have been. Picture judgments, considered together with the sensitometric measurements indicated in Fig. 8, were necessary for the establishment of this criterion.

Similar judgments, considered in relation to physical measurements of picture characteristics, are doubtless necessary for the determination of important production variables, and ultimately of indices of reproduction quality in both color photography and color television.

However, an index of quality of color reproduction cannot be expected as one of the first results of such a program of research. No such index has yet been established for black-and-white tone reproduction. On the other hand, the earlier and more direct results, which indicate optimum adjustments of production variables, are at least as valuable as would be an index of quality. Such an index is of little more than academic interest when the optimum method of reproduction is known and used.

Another part of the study of black-and-white tone reproduction should be mentioned here, because a similar problem and outcome may be expected in color photography and color television. The straight line, A, inclined at 45° in Fig. 9, indicates exact objective reproduction of the luminances, B_o, of a scene, in which the ratio of maximum to minimum luminance is 100. The luminances of both the scene and the reproduction are shown on logarithmic scales. Curve B shows the tone reproduction obtained for that scene by using good photographic techniques. This curve shows the luminances in a picture printed on a semimatte paper. It is apparent that the ratio of maximum to minimum luminances in this print is considerably less than the luminance ratio in the original scene. Consequently, at least some of the luminance contrasts, $\Delta B/B$, in the original scene must be decreased in the print. It might be presumed that the best compromise would be to decrease all luminance contrasts in the same proportion. Such reproduction is represented in the logarithmic plot in Fig. 9 by the straight line, C. Curve B, which represents a print of very good photographic quality, does not follow this straight line. Slopes lower than 45° indicate reduction of luminance contrast in the corresponding range of luminances. It is evident that reduction of contrast is greatest in the high-

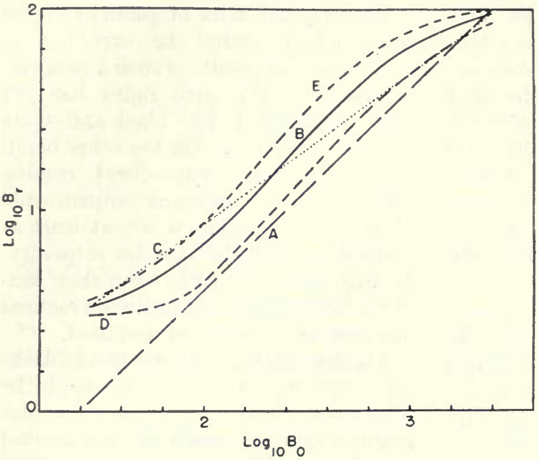

Fig. 9. Tone reproduction curves:

A, "exact reproduction"
B, optimum attainable with semimatte paper
C, proportional reduction of luminance contrasts to fit density range of semimatte paper
D, tone reproduction suitable for scene in which highlights are predominant
E, tone reproduction suitable when only shadow details are important.

lights and shadows, while the middletone contrasts are nearly the same as those in the original scene.

It is interesting to note that photographic limitations are not entirely responsible for the discrepancy between objective reproduction and preferred reproduction.[14] According to Jones,[15] "there are many cases where we know that the perfect objective reproduction, although obtainable, is not the one the majority of judges will choose as of best photographic quality." This effect is real and significant in magnitude. It must be taken into account if the best quality of reproduction is to be obtained. It may be due to subjective as well as objective differences between the situations within which pictures and real scenes are observed. Only a few types of conceivable differences need be mentioned: surroundings, restrictions of field of view, modes of perception (of flat pictures rather than real objects), attitudes, emotions and desires. Jones has shown that the differences of visual sensitivity to luminous contrast caused by quite different conditions of adaptation when viewing the print than when viewing the original scene, must also be taken into consideration.[11] Even if we could account for the effect, we could not neglect it, nor assume that objective reproduction is preferable to any other.

The fact that the print corresponding to Curve *B* is superior to Curves *D* and *E* could not have been determined from the curves alone, nor from any other representation of the results of purely physical measurements of the prints and the original scene. The best print was chosen by inspection, and rules for judging quality of reproduction from curves such as Fig. 9, or from curves showing the compression or expansion of contrasts can be established only by comparing the results of print judgments with the curves. Such rules are therefore psychophysical.

Without psychophysical relationships, the results of optical measurements tell little about the quality of tone reproduction. Such relationships must be rather complex, because curves similar to *D* in Fig. 9 represent optimum reproductions of some scenes, in which all the important details are of high brightness, such as open beach, desert or snowy landscapes. Likewise, prints with curves similar to *E* are best for subjects in which all the important objects are dark. In a qualitative sense, it appears that the objectionability of the compression of luminance contrasts should be weighted by some measure

of the importance of various parts of the luminance scale in reproducing each particular scene.

Investigation of Quality of Color Reproduction

The quality of photographic color reproduction is being studied by a method based on the same principles as were used in the investigation of tone reproduction in black-and-white photography. Series of pictures of a single scene are made with systematic changes of production variables. These pictures are then submitted to a large number of judges, working separately. Measurements are made of all optical quantities that seem relevant. The data from several scenes of different types are used to search for general correspondences between the judged quality of the reproductions and the optical specifications.

The investigation of color photography is much more complicated than that of black-and-white photography, because of the greater number of production variables as well as the greater variety of perceptions. The number of noticeably different tones in a monochrome picture is of the order of a few hundred, while the number of noticeably different colors (including all distinguishable tones of each chromaticity[16]) in a color photograph may be several million. This enormous increase arises from the fact that color photography deals with three independent variables, whereas monochrome reproduction involves only one. The number of distinguishable possibilities in color photography is of the order of the cube of the number in monochrome photography. It is somewhat less than the cube, because not all combinations of the three variables are possible, and variations are not equally noticeable in each of the three variables, nor independent of the values of the others.

Good tone reproduction is just as important in color photography as in black-and-white, but its control and measurement are considerably more complicated. Similarly, the other two variables of color which may be specified by chromaticity are much more complex to control and measure than was the single variable, luminance, in monochrome reproduction.

Some of these complications, especially those of production control, are peculiar to subtractive color photography, in which the optical primaries cannot be modulated independently of each other. Each of the three dyes, which are superimposed to make the picture, absorbs two or even three of the primaries.[17,18] In this respect, at least, color television should be less complex to control and measure than color photography.

The desire to separate the problem of evaluating the quality of color reproduction into two parts, tone reproduction and chromaticity reproduction, is understandable. If successful, it would greatly simplify the questions. But the possibility should not be taken for granted. The problem is not merely simplified; it is changed, and perhaps changed so as to have little relevance to practical color reproduction. Having recognized this danger, we can proceed to examine two attempts that have been made to evaluate color reproduction, both of which have been based on this subdivision of the problem.

In Annex *E* of the Condon report,[1] Judd, Plaza and Balcom assumed that optimum tone reproduction requires the luminances in the reproduction to be proportional to the luminances in the original scene. For their "index of color fidelity," they took the factor of proportionality to be such that white was perfectly reproduced. They then evaluated the errors of reproduction of the luminances of other colors by subtracting the corresponding Munsell values in the original scene and in the reproduction. Munsell values specify

perceptually equal tone differences by equal numerical differences. The method of Judd, Plaza and Balcom[1] heavily penalizes distortions of the ratios of greatly different luminances, which tone reproduction studies have shown to be relatively unimportant, and disregards compressions of luminance contrasts ($\Delta B/B$) which have been found very objectionable, especially in particular portions of the tonal scale that are important in the portrayal of the subject.

After considering many conceivable ways of evaluating the quality of tone reproduction in monochrome pictures, Jones[12] has tentatively suggested that it should be evaluated in terms of departures of luminance gradients from the optimum possible with available materials, rather than in terms of discrepancies of densities (or, presumably, Munsell values) from the densities of the optimum possible reproduction. The enormous amount of data he obtained on the optimum possible tone reproductions of several hundred scenes has not been studied completely, and no final conclusions can yet be announced. It appears that the gradient should be approximately unity (that is, luminance contrast, $\Delta B/B$, should be reproduced practically unchanged) in the central portion of the tonal scale.[11] In other portions of the tonal scale, the amount of the reduction of the gradient (and therefore of luminance contrast) that can be tolerated seems to be related inversely to the importance of such tones and contrasts in the picture.[15] These compressions are optimum in the sense that they make possible the best use of the characteristics of the printing paper, which are dominated by limited density scale and nonlinear characteristic curves of the photographic materials. The key idea in this discussion, the relative importance of contrasts in various portions of the tone scale, is as yet undefined. A suitable definition will have to be operational, in terms of how "importance" is to be evaluated, based on psychophysical studies of the results of judgments of scenes.

No definition of optimum quality, nor rule for evaluating particular reproductions, can be significant or useful, no matter how simple, unless it takes into account the ultimate limitations of the process and psychophysical correlations based on quality judgments of various compromises designed to get the most satisfactory reproductions within those limitations. The fundamental question is "What is the best that can be done under the circumstances?" Like the maximum luminous efficiency, Fig. 3, of sources and maximum luminous transmittances of filters, the answer to this problem will probably include a specification of how to get the best reproduction. That will necessarily specify some such tone reproduction curve as B in Fig. 9. To use any other curve, such as A or C, will result in poorer reproduction. The first will fail because it ignores the circumstance of limited luminance ratio of the paper (or screen, or television tube). The second will fail because it adopts too naive a compromise, excessively reducing important contrasts for the sake of equally prominent reproduction of unimportant contrasts. Finally, any realistic measure of the quality of reproduction will be based on the smallness of departures of slight contrasts from those of the "best" reproduction, rather than on departures of density (or Munsell value) from ideal or exact reproduction, such as was assumed by Judd, Plaza and Balcom.[1]

Like tone reproduction, chromaticity reproduction can be evaluated in terms of discrepancies from the norm. Again, two problems are involved: How to identify the norm, "the best that can be done under the circumstances"? How to measure discrepancies of any actual reproduction from the norm so as to yield a useful figure of merit?

Judd, Plaza and Balcom[1] assumed

that exact colorimetric reproduction was the norm, and measured the discrepancies in Munsell units of hue and chroma. Hue is the name for the characteristic of color sensation according to which red is most distinctively different from green. Munsell hue is a conventional pyschophysical evaluation of hue. Chroma refers to the characteristic which differentiates highly saturated or pure colors from colors of the same hue that are desaturated, for example, by dilution with white or gray. To a fair approximation, if chroma is constant, Munsell hue differences of one unit are equally noticeable, regardless of the particular hues. One unit of Munsell hue difference is approximately twice as noticeable at ten units of chroma as at five units of chroma, and others in proportion to chroma. The complete one-hundred-step hue scale at constant chroma can be represented by a circle, Fig. 10, and the chroma scales for various hues as radii from gray at the center. Since the metrics of this "color map" are approximately Euclidean, one hue step at ten units of chroma is only slightly more noticeable than one half a chroma step. However, Judd, Plaza and Balcom[1] considered hue errors about four times as objectionable as equally noticeable chroma errors. In their evaluation of the seriousness of chromaticity errors, therefore, they penalized various reproductions as much for unit errors of Munsell hue at chroma 10 as for two-unit chroma errors. They did not consider that errors in some hues, such as bluish-green and purples, are much less objectionable than equally noticeable errors of hues of human skin and other familiar materials.

Having weighted all the hue and chroma errors according to the principle described above, they averaged them. In effect, this implies that all equally satisfactory reproduction of the chromaticity, C, in Fig. 10 are represented by points on a diamond-shaped boundary,

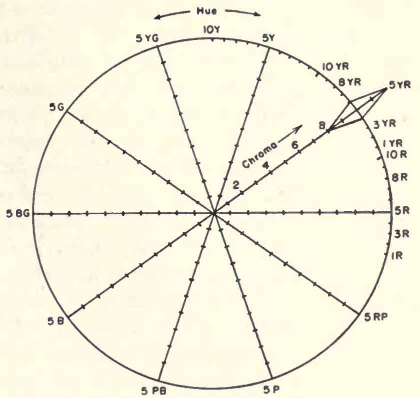

Fig. 10. Diagrammatic representation of Munsell hue circuit at 10 chroma, principal chroma scales and boundary of equally satisfactory reproductions of hue, YR; chroma, 10, according to formula of Judd, Plaza and Balcom.

such as shown on Fig. 10. It also implies that ten small errors are as serious as one error ten times their average, thus repudiating the conventional least-squares principle for minimizing errors. This procedure also ignores the common finding that errors all in one direction are less objectionable than equally great errors in diverse directions.

Series of color prints have been made from well-exposed color-separation negatives of several typical scenes. The prints of each of these series differ in tone reproduction, balance, and in other ways subject to controlled variation. These series have been presented to numerous judges, and their judgments have been compared with results of measurements of various colors in the prints. The various points in Fig. 11 represent the chromaticities of a spot on the forehead of a portrait of a young lady, as reproduced in a number of prints, which exhibit variations of balance from too red or yellow to too blue, and from too green to too pink. Sufficiently small steps of variation were used so as to obtain a number of

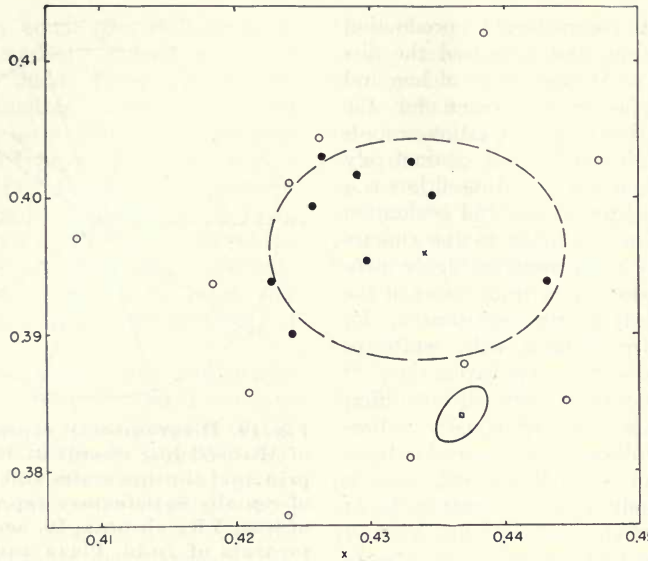

Fig. 11. Chromaticities of forehead of original subject (square), of best reproduction (cross), of reproductions accepted by 50% or more judges (solid dots) and of reproductions accepted by less than 50% of judges (open circles).

These chromaticities are based on the assumption of a 4000 K blackbody source of illumination. Broken curve indicates an estimate of the region of 50% or greater acceptance. The ellipse represents chromaticities just noticeably different from that of the subject's forehead.

satisfactory prints. These prints were submitted to a number of judges who were asked to accept or reject each on the basis of balance alone. The print accepted by the most judges (83%) had the forehead color shown by the cross. The solid dots represent the forehead colors in prints having 50% or greater acceptance, and the open circles show the forehead colors in prints accepted by less than half the observers.

The broken curve in Fig. 11 encloses the probable zone of 50% or greater acceptance. The square below this zone represents the actual color of the girl's forehead, and all points on the ellipse drawn around it represent colors all equally noticeably different from the actual skin color.

Two conclusions are indicated by the diagram in Fig. 11. First, optimum reproduction of skin color is not "exact" reproduction. The print represented by the point closest to the square ("exact reproduction") is rejected almost unanimously as "beefy." On the other hand, when the print of highest acceptance is masked and compared with the original subject, it seems quite pale.

In the second place, the shape of the 50% acceptance zone is similar to the shape of the zone of equally noticeable differences. This finding does not support the decision of Judd, Plaza and Balcom,[1] who assumed four times greater tolerance for chroma errors than for equally noticeable hue errors. Approximately horizontal radii of the 50% acceptance zone and of the equal-noticeability ellipse represent chroma

differences. Vertical radii indicate hue differences.

The discrepancy between "exact" reproduction and preferred reproduction is partly due to distortions inherent in the process, such that a certain discrepancy of a particular color is necessary to permit the best over-all reproduction of all colors in the picture. But, as discussed in the case of monochrome reproduction, it must also be due to differences of the conditions of observation, or of the observer and his attitudes when observing pictures and when observing real objects. Certainly, no such discrepancies should be introduced by a picture window in your living room, nor by a mirror in your dressing room. In such a case, we usually consider that we are looking at the "real thing." Perhaps the farther we get from that attitude, the greater the discrepancy becomes. Perhaps wishful thinking is partly responsible, with or without the acquiescence of fading memory. Certainly, differences of adaptation must play some part, but, for the ordinary range of adapting conditions when viewing scenes and pictures, this cannot account for more than a small fraction of the discrepancy shown in Fig. 11. Whatever the causes, the discrepancy is real, and is typical of the conditions under which photographic portraits are viewed. Since similar distortions and conditions of observation are customary with motion pictures and television, similar discrepancies are likely to be necessary for best results with those media. Face colors in 25 portraits of exhibition quality have been measured. Ten of these were made with the Kodak Flexichrome Process, in which every color is completely and separately under the control of the artist, so that no compromises are necessitated by chromatic distortions of the process. Three others were pastel portraits of children by two professional artists, and two were oil paintings by a prominent contemporary artist. The original subjects were not available for spectrophotometric measurement, but the foreheads of twelve more young people were measured, in order to establish the approximate range of face colors. The range of face colors in the portraits was entirely separate from the range of natural face colors, and the separation of the centers of those ranges is approximately the same as indicated in Fig. 11. Therefore, it seems to be not only quixotic but fallacious to assume exact reproduction to be the norm, or to measure degradations from that basis.

Similar results have been obtained with other colors. Figure 11 should not be regarded as anything other than indicative of the general nature of the results. The directions and amounts of difference between exact reproduction and optimum reproduction are different for every color tested. They must also be different, even for a single color, for processes with essentially different limitations and unavoidable distortions.

Although the 50% acceptance boundary has not exactly the same shape or orientation as the ellipse of equal noticeability in Fig. 11, assumption of such a similarity would be a fair first approximation, and use of this assumption for the general case is suggested until direct determinations are made of the 50% acceptance boundaries for other representative colors. Equal-noticeability ellipses found in a recent investigation[19] are shown in Fig. 12. Ellipses inferred from these have been specified for all locations in the chromaticity diagram by use of the three quantities, g_{11}, $2g_{12}$ and g_{22}, shown by the contour diagrams in Figs. 13 to 15.[20]

The equal-noticeability ellipse centered on any point, x, y, in the chromaticity diagram is defined by the equation

$$g_{11}\,\Delta x^2 + 2g_{12}\,\Delta x\,\Delta y + g_{22}\,\Delta y^2 = 1. \quad (1)$$

The angle, θ, which the major axis makes with the horizontal axis, is given by

$$\tan 2\theta = 2g_{12}/(g_{11} - g_{22}). \quad (2)$$

The value of 2θ is to be chosen from the first two quadrants (so as to make θ less than 90°) when $2g_{12}$ is negative. When $2g_{12}$ is positive, θ is greater than 90°, and therefore 2θ should be chosen from the third or fourth quadrants, depending on the sign of $\tan 2\theta$.

Half the length of the major axis of the equal-noticeability ellipse is given by

$$a = (g_{22} + g_{12}\cot\theta)^{-1/2}. \quad (3)$$

and half the length of the minor axis is given by

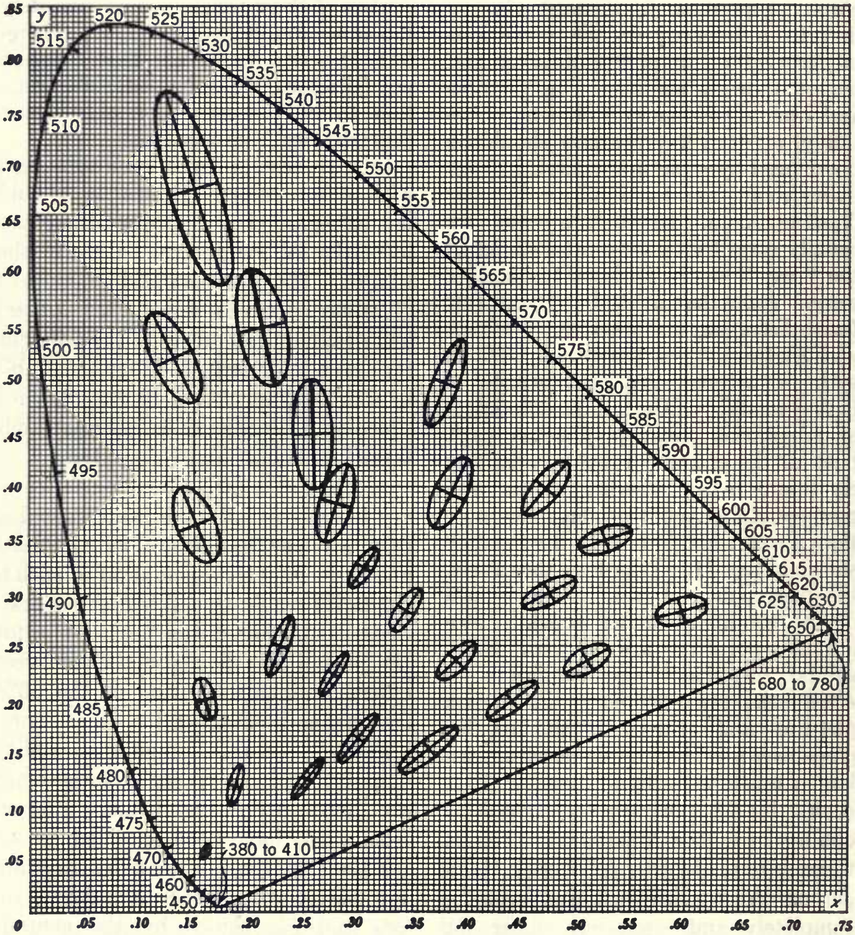

Fig. 12. Equally-noticeable chromaticity differences, represented by radii of ellipses centered on typical colors.

These radii are actually ten times the standard deviation of color matching in a certain colorimeter. Under favorable conditions, color differences equal to one tenth of these radii are just noticeably different.

$$b = (g_{11} - g_{12} \cot \theta)^{-1/2}. \quad (4)$$

Any chromaticity difference, Δx, Δy, that is likely to be encountered as an error in color reproduction by a reasonably satisfactory process may be specified as a multiple (e) of the arbitrary unit of equal noticeability represented by the ellipses in Figs. 11 and 12 by use of the formula

$$e = (g_{11} \Delta x^2 + 2g_{12} \Delta x \Delta y + g_{22} \Delta y^2)^{1/2}. \quad (5)$$

Silberstein[21] and MacAdam[16] have shown how to use such data are represented by Figs. 13 to 15, to compute the number of just-noticeably different chromaticities represented by any area of the chromaticity diagram. Symbolically, this number is proportional to the surface integral,

$$\int_s (g_{11}g_{22} - g_{12}^2)^{1/2} \, dx \, dy.$$

For the triangular gamut of the "C"

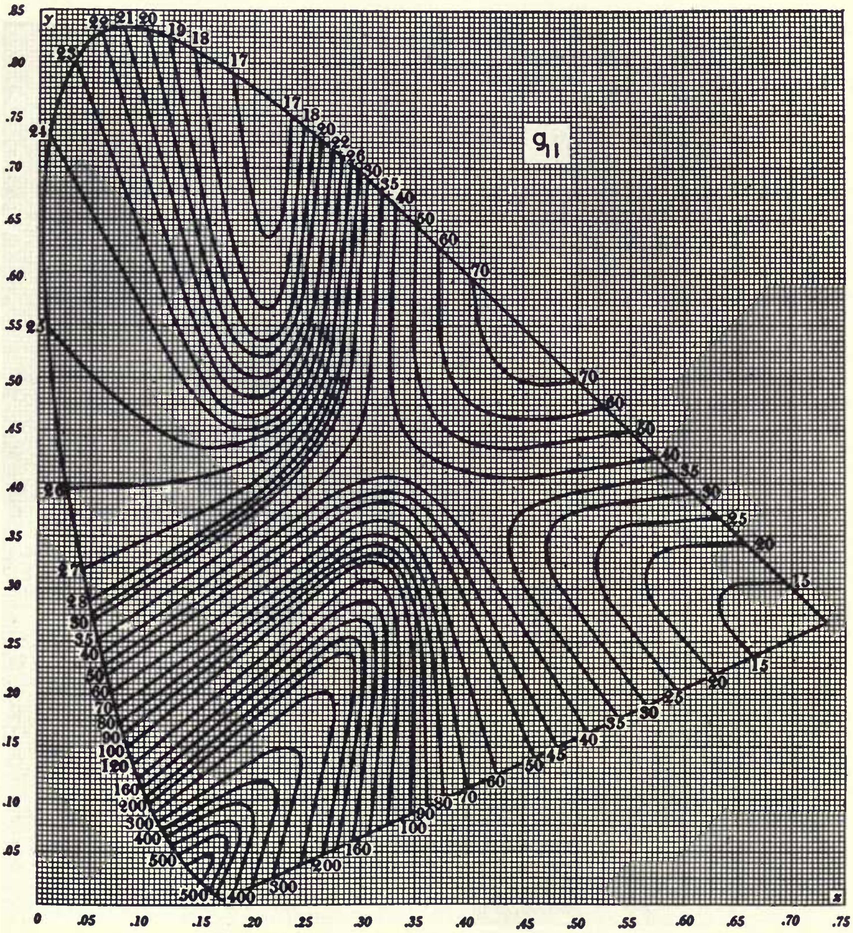

Fig. 13. Distribution of values of first metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

set of primaries, shown in Fig. 4, the number of just-noticeably different chromaticities is about five thousand. For the "A" set, whose gamut is shown in Fig. 5, the number of just-noticeably different chromaticities is about three thousand. These numbers may be compared with seventeen thousand, an estimate of the total number of just-noticeably different chromaticities, up to and including spectrally pure colors.[16]

It is conceivable that some such formula as (5) may be useful for expressing results of the kind shown in Fig. 11. For this purpose, two modifications would be essential: first, to compute the deviations, Δx, Δy, from the geometric center of the 50% acceptance boundary and, second, to modify the values of the metric coefficients, g_{11}, $2g_{12}$, g_{22}, in accordance with the differences of size, shape and orientation of the acceptance boundary and the ellipse of equal noticeability.

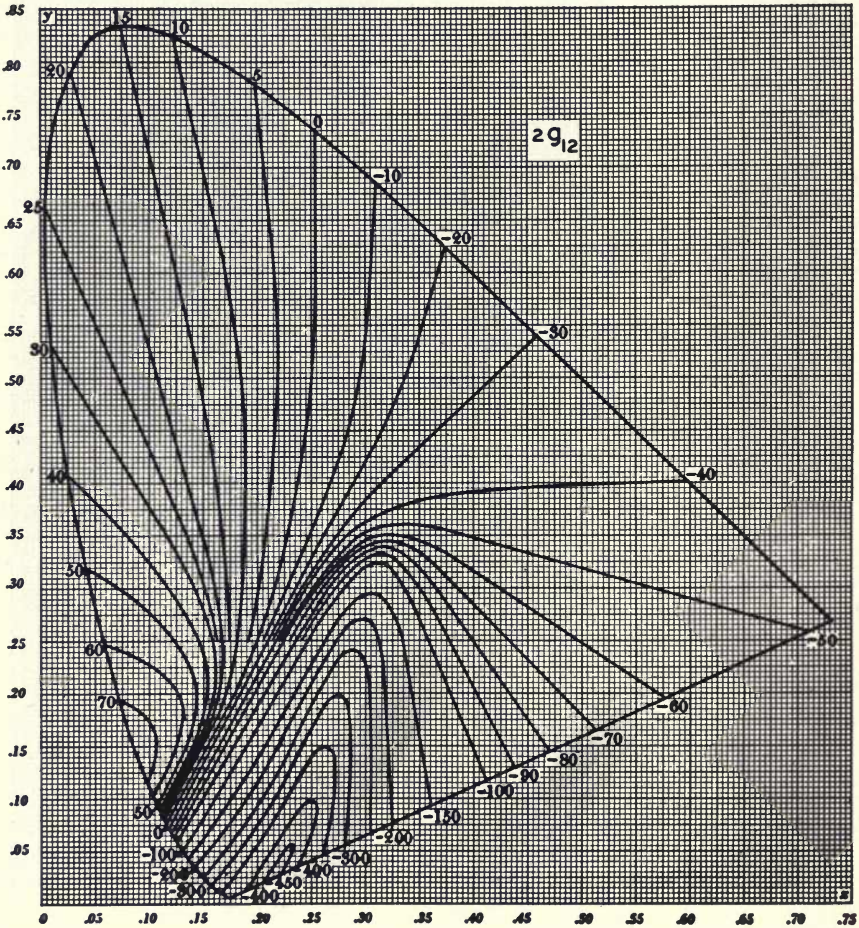

Fig. 14. Distribution of values of second metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

The centers of the acceptance boundaries, and also their shapes, specified by g_{11}', $2g_{12}'$, g_{22}', may be expected to differ from process to process and for various classes of observing conditions. Thus, different kinds of distortions of the relations of reproduced colors, and various interactions of the production variables, such as the mutual interference of functions of the dyes in subtractive processes, mentioned previously, can be expected to result in different centers and shapes of the acceptance boundaries. Similarly, various angular subtenses of the picture from the point of view of the observer, and various distributions of light in the surroundings can be expected to call for variations of the centers and the shapes of the acceptance boundaries. Such must also result from various types of interest, for example: casual, as in the case of variety shows; or intent on details, such as the color of the

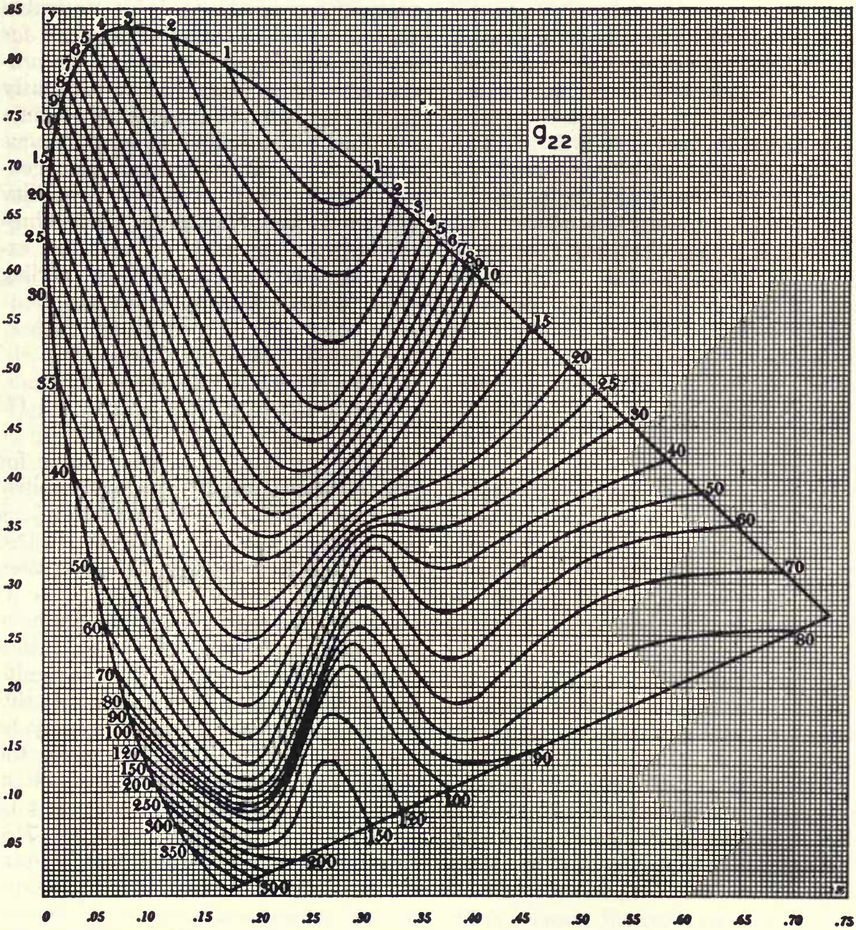

Fig. 15. Distribution of values of third metric coefficient in Formula (5) for noticeability of chromaticity differences. Numerical values shown should all be multiplied by 10^4.

shirt of a jockey in a horse race; or professional, such as close-ups of surgery.

It is conceivable that results of statistical studies of the reproductions of a number of colors can be combined by use of terms of this form. The root-mean-square error of reproduction might, for example, be computed by

$$E = \left[\sum_{i=1}^{i=n} (g_{11}' \Delta x^2 + 2g_{12}' \Delta x \Delta y + g_{22}' \Delta y^2) i/n\right]^{1/2}. \tag{6}$$

Adjustment of a process to reduce E to the smallest value employs the customary principle of least-squares adjustment.

In order to use such a formula to obtain a figure of merit for chromaticity reproduction, the optimum reproductions (that is, the centers of the 50% acceptance boundaries) will have to be determined for a number of colors that are typical and important in color pictures. The sizes and shapes of the acceptance boundaries will also be found during that psychophysical analysis, thus indicating the required modifications, g_{11}', $2g_{12}'$, g_{22}', of the metric coefficients.

Having considered the separated problems of how to evaluate departures from optimum tone reproduction and how to evaluate departures from optimum chromaticity reproduction, it remains to consider how we can combine such results so as to evaluate departures from optimum color reproduction, which almost invariably consist of errors of both tone and chromaticity reproduction.

Judd, Plaza and Balcom[1] assumed that such errors could be weighted by their relative importance and simply averaged. They decided that one Munsell value step is as important in a color picture as two Munsell chroma steps, and they assigned relative weights to discrepancies from "exact" tone and chromaticity reproduction in accordance with that conclusion. Analogous to the case of the simple addition of weighted hue and chroma "errors," this implies that an octahedral surface, having three diamond-shaped principal cross-sections in the hue-chroma, hue-value and chroma-value planes, represents all equally objectionable reproductions of a single color in the original scene.

No attempt has yet been made to combine results from the psychophysical studies of tone reproduction and chromaticity reproduction. It is conceivable that the kind of formula suggested for statistical ratings of chromaticity reproductions can be generalized, analogously to the way in which the original formula for the noticeability of equiluminous chromaticity differences has been generalized to measure the noticeability of combined luminance and chromaticity differences.[22] The latter extension was accomplished by adding three terms to the simpler formula

$$e = (g_{11} \Delta x^2 \pm 2g_{12} \Delta x \Delta y + g_{22} \Delta y^2 + 2g_{23} \Delta y \Delta \log B + g_{33}(\Delta \log B)^2 + 2g_{13} \Delta x \Delta \log B)^{1/2}. \tag{7}$$

The values of $g_{11}, \ldots, g_{13}$ suitable for the measurement of the noticeability of color differences were published for a large number of typical colors.[22] No interpolation procedure has yet been published.

Since tone reproduction studies have shown that contrast reductions, rather than "errors" of luminance, are significant, the use of a measure of this reduction in place of $\Delta \log B$ may be more appropriate in a formula for the figure of merit of color reproduction. Luminous contrast reduction might be measured by $1 - (\Delta B_r/B_r)/(\Delta B_o/B_o)$. To a good approximation, this is equal to $1 - \Delta \log B_r / \Delta \log B_o$. If the slope of the reproduction curve is denoted by M_r, then $1 - M_r$ represents the same approximation to the expression for luminous contrast reduction. This

quantity has been studied by Jones, as the most promising measure of loss of tone reproduction.[23] If we adopt the symbol, $\Delta M = 1 - M_r$, then a conceivable formula with which to measure a particular error of color reproduction is

$$e' = (g_{11}' \Delta x^2 + 2g_{12}' \Delta x \Delta y + g_{22}' \Delta y^2 + 2g_{23}' \Delta y \Delta M + g_{33}' \Delta M^2 + 2g_{13}' \Delta x \Delta M)^{1/2}. \tag{8}$$

The g's in this formula may be expected to differ from those in the formula for the noticeability of color differences, because of the replacement of $\Delta \log B$ by ΔM and because the 50% acceptance boundary in the chromaticity diagram (Fig. 11) is different from the ellipse of equal noticeability. It should also be noted again that Δx and Δy should be measured from the optimum reproduction, such as indicated in Fig. 11, rather than from the chromaticity of the original. It is also to be noted that the relative magnitudes of the coefficients in the first and last groups of three terms in Eq. (7) depend very much on the conditions of observation. For instance, the ratio of g_{33} to g_{11} is fifty thousand times as great when the observers' task is to read small letters that differ only slightly in color from their background, than when they are asked to rate various attempted "matches" presented in the form of uniform and nearly gray color-prints, 3 × 4 in. large, mounted on white cards with unremovable, inch-wide borders. This factor is the square of the ratio (225) of the luminance contrasts equivalent to a prescribed chromatic contrast under the two circumstances.[24]

When a number of reproduction errors are to be averaged, it will probably be necessary to weight them according to their importance. To some extent, these weights will depend upon the subject matter of each picture. The color of human skin will frequently be weighted heavily and other colors in accordance with their familiarity, emotional associations and frequency of their occurrence. Furthermore, those weights should probably depend upon the luminances of the colors, relative to the tonal range of the scene. Certainly, optimum rendering of the chromaticity as well as the luminance of the face of a person in the deeply shadowed background of a scene is less important than for the face of a person in the brightly lighted foreground. It therefore seems probable that the "importance" factors, which were first suggested in the discussion of optimum tone reproduction, should be applied not only to the terms expressive of luminous contrast reproduction, but to all terms alike. For this reason, it was suggested that it is probably inadvisable to subdivide the problem of specifying quality of color reproduction into two parts, dealing separately with tone reproduction and chromaticity reproduction.

If all these conjectures are combined, a general form can be suggested for the root-mean-square error of color reproduction:

$$E = \left[\sum_{i=1}^{i=n} W_i(g_{11}' \Delta x^2 + 2g_{12}' \Delta x \Delta y + g_{22}' \Delta y^2 + 2g_{23}' \Delta y \Delta M + g_{33}' \Delta M^2 + 2g_{13}' \Delta x \Delta M)_i/n\right]^{1/2}. \tag{9}$$

For this evaluation, Δx and Δy should be measured from the optimum reproduction. The contrast reduction term

$$\Delta M = 1 - \Delta \log B_r / \Delta \log B_o$$

is primarily a function of B_r. Any residual dependence of ΔM on x, y is an indication of unstable balance of the system, although not necessarily a suitable measure of balance.

Judging from analogous data on noticeability of color differences, g_{11}', $\ldots$, g_{13}' depend primarily on chromaticity for all comfortable reading levels of luminance (above about one foot-Lambert). The weights, W_i, which could be combined with g_{11}', $\ldots$, g_{13}', require separate investigation and will

probably vary most markedly with luminance, B_r.

A "figure of merit" for color reproduction can be derived only by adoption of some arbitrary convention. If g_{11}', ..., g_{13}' are based on the 50% acceptance boundary, as in Fig. 11, then an average error, E, equal to 1 means that the picture would be rejected by 50% of the judges. To a first approximation, the percentage of judges who would reject a reproduction having some other value of E would be proportional to the ordinate of the probability integral, in which the usually tabulated abscissa, hx, is 0.477 E. Thus, for $E = 2$, $hx = 0.954$, and it is to be expected that the reproduction would be rejected by about 82% of the judges. For $E = 0.5$, it may be expected to be rejected by about 26%. This direct interpretation of E is lost if a figure of merit of the form, $100(1 - E/C)$, suggested by Judd, Plaza and Balcom[1] is adopted, C being some arbitrary constant, such as 30, in the instance cited. If a figure of merit is desired, which shall be high for the most satisfactory reproductions, and low but never negative for the worst reproductions, perhaps the percentage of judges accepting the reproduction will serve. Thus, from these examples, the figure of merit corresponding to $E = 1$ would be $F = 50$; for $E = 2$, F would be 18; and for $E = 0.5$, $F = 74$. For other values of E, F can be computed easily by use of any table of the probability integral.

Such an interpretation makes it evident that figures of merit cannot be combined so as to predict the quality of reproduction of a two-stage process, such as copying or televising a color photograph. The errors of reproduction of each process are vectors, which may compensate each other as well as accumulate. Furthermore, the errors are not measured from an absolute base, but from subjectively optimum reproductions. For these and many other reasons, it seems futile to hope for a figure of merit which can be multiplied, or combined in any way, to predict the quality of reproduction of combined processes. The figure of merit of a combined process can be determined only by application of the principles, and probably by use of the same formula as for direct reproduction.

Retrospect and Prospect

The evaluation of quality of color reproduction poses many complex problems. The order in which they have been investigated is an historical accident, arising from the fact that black-and-white pictures were made first and were important long before color photographs. The additional complexity of the latter, not only the complexity of their production but the complexity of their appearance, further delayed investigations aimed at evaluating their quality.

It is by no means certain that results of tone reproduction studies of black-and-white pictures can be carried over, and merely supplemented by studies of chromaticity reproduction. Optimum reproduction needs to be identified. Since it depends upon the limitations of the reproduction process, as well as upon human vision and judgment, optimum reproduction will probably have to be determined for each process separately.

Projected photographic transparencies share many, but not all, of the limitations of television. To the extent to which their limitations are equivalent, results for one process can probably be applied to the other. Prints on paper suffer from much more severe limitations. Only the principles of investigation, not specific results, can be expected to apply to motion pictures and to television. Most of the tone reproduction studies have been made on reflection prints, and investigations of quality of color photographs are almost entirely concerned with re-

flection prints. Perhaps this is because the limitations of paper prints are so serious. Every effort has to be made to get the best results possible under the circumstances. However, it is only a matter of time before the limitations inherent in motion pictures and in television force more systematic studies of reproduction quality. For this reason, this account is given of the principles of investigation which have been used in tone reproduction studies of black-and-white prints, and of the way in which the method seems to be applicable to color photography.

This program may seem elaborate, but it does not seem wise to base important decisions on less direct evidence. The investigation of color quality may be expected to be easier, quicker, more systematic and complete in color television than in color photography, because changes in production variables can be made more easily, with continuous gradations if desirable, and reproducibly, by electronic controls. Different pictures have to be made for color photography, and photographic processing controls are less direct, less convenient to change and less reproducible than electronic controls. Each desired change requires a long time in color photography, whereas most changes could be made subject to nearly instantaneous control in color television. The variety of tone reproduction curves (transfer curves) obtainable with television should be much greater than in photography, and a more complete and systematic search for the optimum quality of color reproduction should be possible.

The program is to vary the production controls in systematic manners, measure the resulting color reproduction in the best way known (e.g., the ICI method at the present time), submit the reproductions to visual judgment, and study the judgment data in comparison with the measurements in order to find significant correlations. The growing experience of such studies of color photography is suggested as a guide. Particular studies should be made of skin colors, gray scales and other crucial colors. If certain conditions seem to be identified as giving optimum reproduction, it would be very desirable to set them up and verify the fact, or to find exceptions which can be used to improve the concept of optimum. Deviations of measured characteristics of other reproductions should then be computed, or directly measured, from the optimum. Quality ratings, either directly reported by judges or based on the proportion of judges who accept the reproduction as satisfactory, can then be correlated with the deviations from optimum reproduction. Only in this general fashion can we establish a method for assessing various kinds of deviations and their combinations.

Preliminary estimates of optimum reproduction and of seriousness of deviations may be based tentatively on results of studies of noticeability of color differences and on fragmentary results of studies of color photography. These estimates can be improved as various parts of the program are carried out. This beginning offers a basis for growth. New results can be grafted on these roots.

The formulas shown in this account are extremely tentative. They are merely suggestive of the nature of the problem, and of conceivable forms of the solution. These may prove unnecessarily complex. They are sufficiently definite in form to guide research, and yet they are sufficiently flexible so that their accuracy can be improved with each increase of our knowledge. In this sense they symbolize a program of research, and a goal.

One conclusion, only, can be stated with assurance, that the successful index of quality of color reproduction will ultimately be established as a result of psychophysical analysis of

judgments of picture quality, referred unambiguously to the pictures by measurements of relevant optical quantities.

References

1. Senate Advisory Committee on Color Television, E. U. Condon, Chairman, "Present Status of Color Television," Senate Document 197, 81st Congress, Second Session, 1950; reprinted in *Proc. I.R.E.*, vol. 38, pp. 980–1002, Sept., 1950.
2. Staff of Color Measurements Laboratory, MIT, under direction of A. C. Hardy, *Handbook of Colorimetry*, Massachusetts Institute of Technology Press, Cambridge, Mass., 1936.
3. W. D. Wright, *The Measurement of Colour*, Adam Hilger Co. Ltd., London, 1944.
4. P. J. Bouma, *Physical Aspects of Colour*, N. V. Philips' Gloeilampenfabrieken, Eindhoven, 1944.
5. D. L. MacAdam, "The fundamentals of color measurement," *Jour. SMPE*, vol. 31, pp. 343–348, Oct. 1938.
6. Committee on Colorimetry, L. A. Jones, Chairman, "Quantitative data and methods for colorimetry," *J. Opt. Soc. Amer.*, vol. 34, pp. 633–688, 1944.
7. D. L. MacAdam, "Maximum attainable luminous efficiency of various chromaticities," *J. Opt. Soc. Amer.*, vol. 40, p. 120, 1950.
8. D. L. MacAdam, "Maximum visual efficiency of colored materials," *J. Opt. Soc. Amer.*, vol. 25, pp. 361–367, 1935.
9. F. J. Bingley, "Application of projective geometry to the theory of color mixture," *Proc. I.R.E.*, vol. 36, pp. 709–723, 1948.
10. M. E. Clarkson and T. Vickerstaff, "Brightness and hue of present-day dyes in relation to colour photography," *Phot. Jour.*, vol. 88B, pp. 26–39, 1948.
11. L. A. Jones, "Recent developments in the theory and practice of tone reproduction," *Phot. Jour.*, vol. 89B, pp. 126–151, 1949.
12. L. A. Jones, "Psychophysics and photography," *J. Opt. Soc. Amer.*, vol. 34, pp. 66–88, 1944.
13. American Standards Association, "Standard Method for Determining Photographic Speed and Speed Number, Z38.2.1," New York, 1946.
14. R. M. Evans, *Introduction to Color*, Wiley and Sons, New York, 1947.
15. L. A. Jones, "The psychophysical evaluation of the quality of photographic reproductions," *PSA Jour.*, 1951 (in press).
16. D. L. MacAdam, "Note on the number of distinct chromaticities," *J. Opt. Soc. Amer.*, vol. 37, pp. 308–309, 1947.
17. D. L. MacAdam, "Subtractive color mixture and color photography," *J. Opt. Soc. Amer.*, vol. 28, pp. 466–480, 1938.
18. D. L. MacAdam, "Physics in color photography," *J. Appl. Phys.*, vol. 11, pp. 46–55, 1940.
19. D. L. MacAdam, "Visual sensitivities to color differences in daylight," *J. Opt. Soc. Amer.*, vol. 32, pp. 247–274, 1942.
20. D. L. MacAdam, "Specification of small chromaticity differences," *J. Opt. Soc. Amer.*, vol. 33, pp. 18–26, 1943.
21. L. Silberstein, "Investigations on the intrinsic properties of the color domain, II," *J. Opt. Soc. Amer.*, vol. 33, pp. 1–10, 1943.
22. W. R. J. Brown and D. L. MacAdam, "Visual sensitivities to combined chromaticity and luminance differences," *J. Opt. Soc. Amer.*, vol. 39, pp. 808–834, 1949.
23. L. A. Jones, "The evaluation of negative film speeds in terms of print quality," *J. Frank. Inst.*, vol. 227, pp. 297–544, 1939.
24. D. L. MacAdam, "Color discrimination and the influence of color contrast on visual acuity," *Rev. d'Optique*, vol. 28, pp. 161–173, 1949.

A Time-Motion Study by Methods of High-Speed Cinematography

By Henry W. Baer, Bernard F. Cohlan and Arthur R. Gold

In this paper an attempt has been made to evaluate a method of motion study pertaining to moving machinery. The test object was a 13-ton capacity punch press and the motion study was performed with a high-speed motion picture camera. It is shown that the motion picture camera produces: (1) a visual indication of the actual occurrence which allows an understanding that nonvisual means could not afford; (2) a method of study which does not influence the system studied in the least; and (3) a record of the occurrence which has very little inherent error.

The advent of high-speed cinematography places a valuable tool in the hands of the research worker. Motion picture photography has already proved itself in many phases of science, but in some cases it is necessary to test its applicability and determine the error in the resulting record.

A common method of investigation of moving machinery has been the use of recording devices such as strain gage bridges, oscillographs, photoelectric cells, and others. In this investigation an attempt has been made to determine the merits of data obtained from a high-speed motion picture camera.

All tests were conducted in one of the Engineering Research Laboratories of the University of California, Los Angeles campus. The research was conducted by the writers who were under the general direction of Professor D. Rosenthal, and with technical advice of Mr. A. Keller for the use of high-speed photographic equipment.

Description of Equipment

A standard 13-ton capacity punch press was chosen as a typical example of moving machinery. As a result of a previous investigation,* it was possible to operate the press near its full capacity. The load simulator consisted of a steel, cone-shaped indentor penetrating an aluminum block. Aluminum was chosen to reduce wear on the indentor, thus eliminating a variable due to changes in indentor form. The punch

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* The previous investigation consisted of a thorough stress analysis of the entire punch-press structure to determine the maximum allowable load for continuous operation.

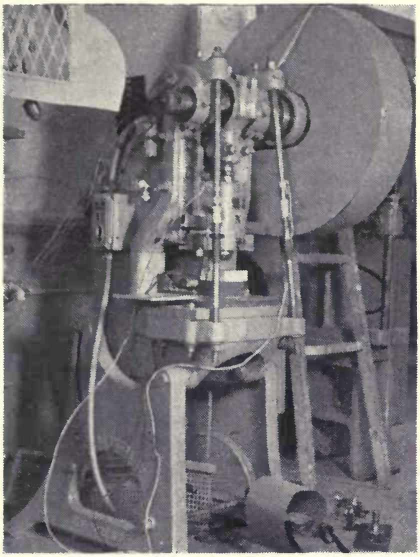

Fig. 1. Punch press.

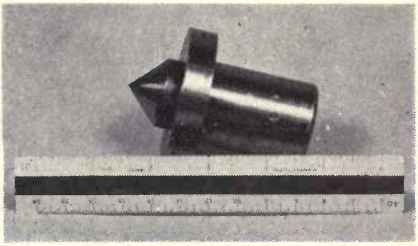

Fig. 2. Load simulator.

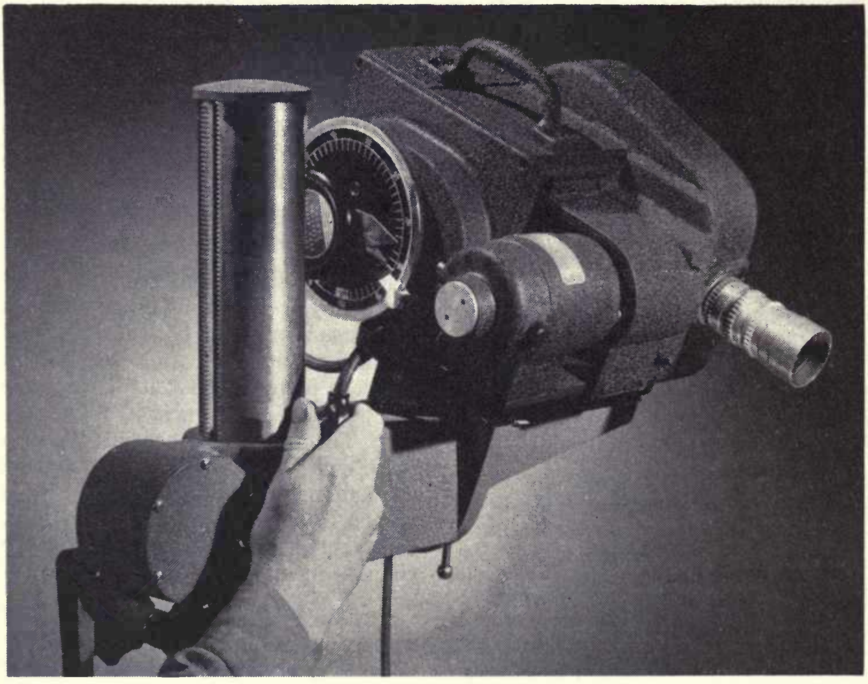

Fig. 3. Kodak High-Speed Camera.

press and load simulator are shown in Figs. 1 and 2.

The photographic measurements were obtained by a Kodak High-Speed Camera (see Fig. 3). This camera uses 16-mm film and has a maximum speed of 3000 frames/sec. The lens used was of 2½-inch focal length.

Only ram displacements were recorded. A pointer attached to the ram was photographed against a stationary scale along with a small clock marking time (Fig. 4). The clock was calibrated in milliseconds which proved to be of sufficient sensitivity for the purpose. High-speed motion pictures of the pointer, the scale, and the clock were taken while the press was in motion.

The force exerted by the ram was determined by an inked stylus oscillograph with a null-type strain gage bridge input. This force was determined from the elastic strain induced in the press tie rods (Fig. 1). To this end a pair of electric strain gages was mounted on each tie rod (Fig. 5). The strain gages in each pair were connected in series to eliminate the effect of accidental bending. The record of force was calibrated by loading the ram statically. This calibration of force was considered as an approximation only since the actual loads were dynamic ones. The time constant of the oscillograph was such that only the average value of force could be measured with reasonable accu-

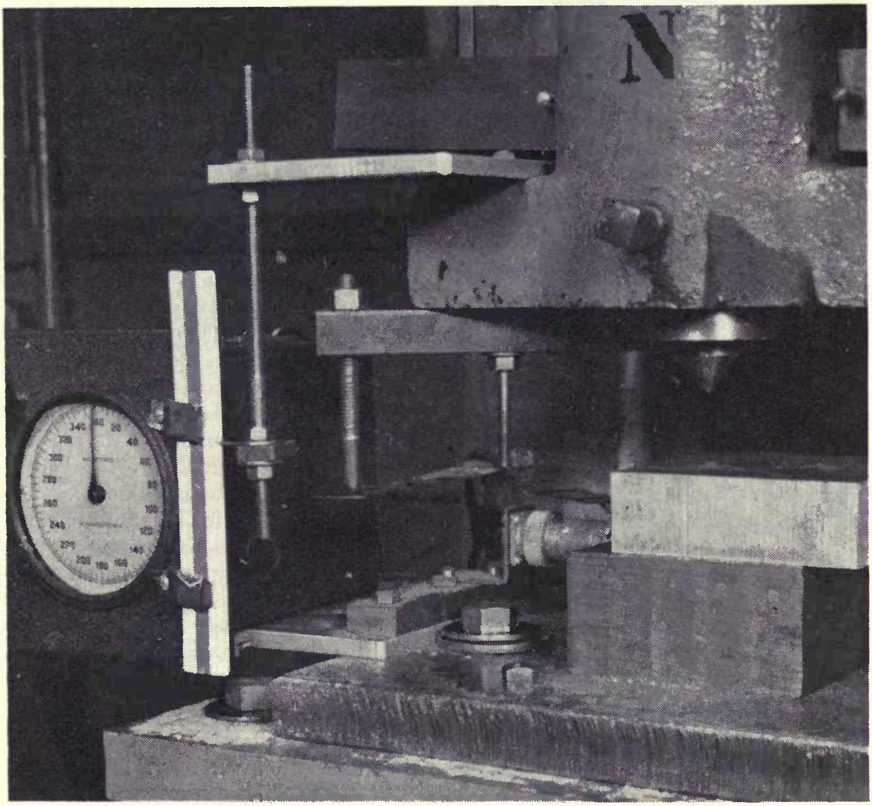

Fig. 4. Ram, pointer, stationary scale and clock.

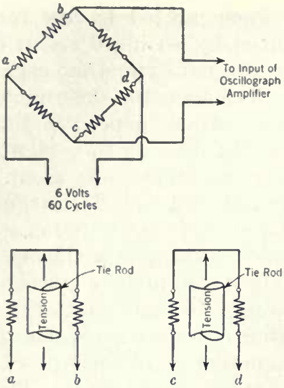

Fig. 5. Schematic arrangement of electric strain gages.

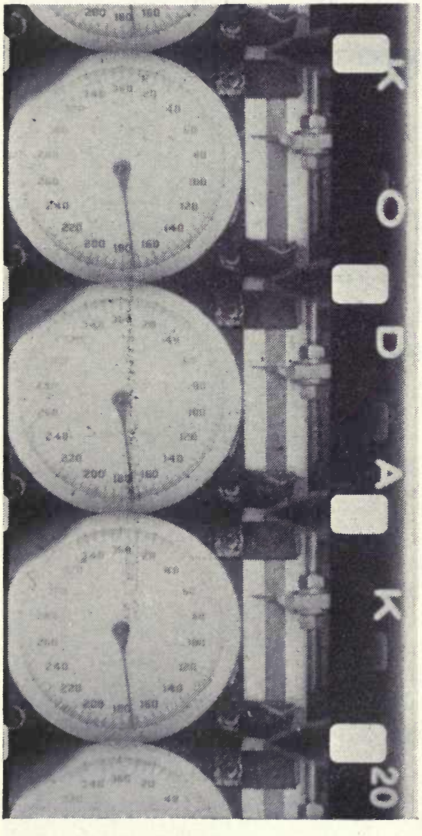

Fig. 6. Section of recording film (×4).

racy; therefore, the force indication was used only as a guide to operation within the capacity of the press.

Experimental Procedure

Experimental data were obtained from photographic recordings of the press operation. The operation consisted of repeated impacts between the indentor and the aluminum specimen, simulating an actual punch-press operation. The resulting films were translated into ram displacement vs. time curves to facilitate study.

These data were reduced by taking readings of time and displacement from the film (see Fig. 6) by means of a low-power binocular microscope. The maximum error incurred in the time measurement was estimated to be 1 msec (millisecond) and the maximum error in the displacement measurement was estimated to be 0.005 in. The reduced photographic data are shown in Fig. 7. Two curves are shown, one for load, and one for no-load motion of the ram.

Experimental Results

The no-load curve is essentially a cosine curve with an amplitude of 1.25 in. and a period of 460 msec. The load curve departs from a cosine curve during impact and after impact it returns to a cosine curve as the flywheel returns to no-load energy conditions. The displacement amplitude due to this load is 1.19 in. and its period is 480 msec. The difference of 0.06 in. in amplitude between load and no-load curves can be attributed to clearance between press components which manifests itself as backlash. The load curve indicates that the ram came to rest upon impact and remained at rest until the backlash was taken up. Upon absorption of the backlash the indentor was driven into the specimen. This portion of the stroke actually did the plastic and elastic work. At completion of the work interval the ram force was removed and the

stored elastic energy raised the ram. Here again the ram remained stationary during the absorption of the backlash and then accelerated to a normal energy condition with respect to its position.

Analysis of Results

The value of a photographic analysis of this type can be demonstrated in two ways: (1) by a comparison of the experimental findings with the expected theoretical performance; and (2) by the detection of occurrences that would not ordinarily be expected from theoretical considerations. In accordance with the first principle the following theoretical discussion will indicate a good correlation between the experiment and theory.

Since it is reasonable to assume backlash in the driving mechanism—and a simple calculation reveals that the indentor velocity is relatively small when impact occurs—, it can readily be seen that little work can be done until all backlash has been taken up. Therefore, it is reasonable to believe that the indentor comes to rest for a short period of time, while the backlash is absorbed. At the end of this time further penetration occurs until the limit of the stroke has been reached. Before the ram can again be lifted the backlash must once more be taken up. During this time the indented metal gives up its elastic energy to the ram, thus lifting it a short distance. Here again the ram remains at rest while the backlash is absorbed. At this point the ram undergoes motion which does not seem consistent with the predicted path indicated by the no-load curve. This is an occurrence which was not predicted from theory and which indicates the sensitivity of the method. At first thought it would seem that the ram could not be lifted until a time later than that indicated by the no-load curve for the same displacement. The subsequent discussion appears to substantiate the experimental findings just described.

During the impact of the ram with the specimen the flywheel and motor speed greatly decrease. Consideration of the torque-speed characteristics (Fig. 8) of an induction motor shows that slightly decreased speed is associated with a

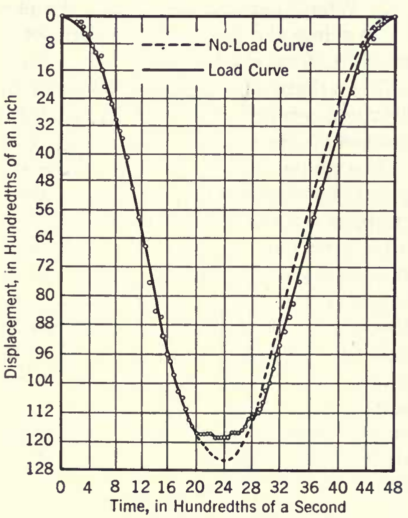

Fig. 7. Displacement-time curves.

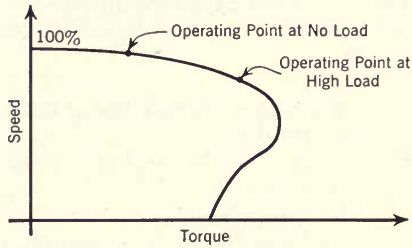

Fig. 8. Speed-torque characteristics.

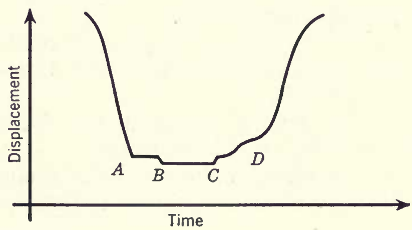

Fig. 9. Schematic displacement-time curve.

highly increased torque. Since in induction motors the assumption is made that the torque is proportional to the current, it seems reasonable that a torque requirement change will cause a current change. This shows that during impact a current surge occurs.

Examination of Fig. 9 shows that the flywheel and motor see no load from points A to B and a large load from points B to C. During the period A–B the motor tends toward zero slip and during period B–C the slip increases to some large value. This change in speed and torque causes a large surge of current which tends to continue into the period C–D due to the inductive properties of the motor. This surge current could accelerate the driving system to a point where it could lift the ram at an earlier time than that indicated by the no-load curve. Under this high acceleration the flywheel would return to a normal energy level in an extremely short time after impact, as was actually indicated by the experiment.

Thus the high-speed camera has shown an occurrence that could have been overlooked by a recording system which possesses a lesser degree of perception.

Final Evaluation of High-Speed Cinematography

1. Versatile; can be adapted to a wide variety of uses.
2. The photographic equipment is stable and unaffected by surrounding conditions.
3. The film provides a reliable and permanent data record.
4. The equipment requires a minimum of installation time for time-motion studies.
5. The method allows direct visual study of high-speed occurrences.
6. The photographic method does not alter the system being studied as the system is completely isolated from the recording device.
7. The error introduced in translation from the film to the reduced form is negligible in most applications.
8. The ability of the photographic method to detect rapid changes is limited predominantly by the maximum camera speed. Its ability to detect small magnitude changes is limited primarily by the magnifying and resolving power of the lens and also by the grain size of the film. These limits far exceed the limits of other recording systems of comparable cost and complexity.
9. The photographic method has a disadvantage in that the experimental record cannot be used until the film has been processed which means delay and increased research cost.

Recommended Further Studies

In subsequent studies of the problem an attempt should be made to use high-speed cinematography in the determination of the following factors related to a punch-press operation:

1. What are the energy-time relations between flywheel and ram under several kinds of simulated loads?
2. What percentage of its kinetic energy does the flywheel lose during the interval of maximum work?
3. Is there a lag between minimum flywheel energy and maximum force exerted on the ram?

The above factors should be investigated by high-speed cinematography methods by establishing relationships of time functions of displacement, force, and flywheel revolution rates. It is hoped that a satisfactory answer to the above additional questions in conjunction with the data as presented in this paper could serve as a guide in future punch-press design. The recommended experiments would also demonstrate the utility of high-speed cinematography.

16-Mm Film Maintenance Cost and Analysis of Damages

By Ernest Tiemann and Dencil Rich

In the first part of the study, the maintenance costs of 192 prints of sound motion picture films in active circulation between 1942 and 1950 are analyzed. In the second part, an attempt is made to analyze the damages to motion pictures distributed during the course of one year of operation. Circulation figures and percentages for each month of the year are compared with the amount and percentages of damages occurring during the same period.

16-Mm Film Maintenance Costs

Increased use of the 16-mm film has brought into existence hundreds of new film libraries. Those responsible for the maintenance and supervision of these libraries are extremely interested in the maintenance costs of 16-mm films over an extended period of time. At institutes, conferences, and workshops, the question often arises: "How much does it cost to maintain a 16-mm film in a satisfactory condition over a period of from five to ten years?" An answer to this problem also makes it possible to plan amortization schedules including the original cost and maintenance expenditures.

The Audio-Visual Center of Indiana University has maintained an accurate inspection record of all films accessioned after July 1, 1942. Recently it was decided to make a study of all prints of films purchased during the fiscal year of July 1, 1942, to June 30, 1943, to determine the maintenance costs of all those prints that were still in active use. Of the 282 prints purchased during the period between July 1, 1942, and June 30, 1943, 192 prints were in continuous circulation till July 1, 1950. Accessioning, print control, inspection and booking cards were studied and analyzed for each of the 192 prints. By checking the bookkeeping records for each of the 192 prints, it was found that they were used a total of 18,149 days for an average of 94.5 days per print.

Eighty-three of the 192 prints were damaged to the extent that replacement footage was needed. One hundred and ten different replacement parts were added, requiring a total of 5,264 ft of replacement film. All of the films except one were black-and-white. The cost of replacement parts amounted to $476.36; the average cost of replacement footage per print amounted to approximately $2.50.

Although this preliminary study is in

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no way conclusive, it does indicate that for this particular group of prints, maintenance costs for replacement footage alone amounted to approximately $2.50 a print over a seven-year period. It is assumed that replacement costs will vary, depending upon these variable factors: (a) the number of bookings per print, (b) standards of maintenance, (c) comparative number of black-and-white and color prints, and (d) the cost of replacement footage.

Analysis of 16-Mm Film Damages

One of the most important factors influencing the maintenance costs of 16-mm films is the care given the films during the period when they are used by the customer. Each film library has a responsibility of keeping its prints in the best possible condition. To do this requires a systematic inspection of each print each time after it has been projected.

As a result of years of experience in inspecting films, the Audio-Visual Center of Indiana University has developed a very detailed classification of film damage which is consistently used in making an analysis of all types of film damages. Each inspector has the responsibility of preparing a report of each film damage, and periodically these reports are carefully studied and analyzed.

Recently a detailed study was made of all film damages that occurred during a full year of operation. As the result of this analysis, it was possible to study the factors which brought about the film damage and to chart a course of action in attempting to decrease future damages.

Table I. Damage Types.

Code No.	Description
1.	Chipped sprocket holes
2.	Teeth marks between sprocket holes, tears into frame
3.	Teeth marks on sound track
4.	Chipped sprocket holes, tears into frame
5.	Teeth marks between sprocket holes
6.	Chipped sprocket holes, single breaks to edge of film
7.	Teeth marks between sprocket holes, single breaks to edge of film
8.	Chipped sprocket holes, teeth marks between sprocket holes
9.	Nicks on frame side of sprocket holes
10.	Teeth marks in frame
11.	Tears into frame from sprocket holes
12.	Teeth marks in frame and on sound track
13.	Chipped sprocket holes, nicks on frame side of sprocket holes
14.	Chipped sprocket holes, teeth marks in frame
15.	Chipped sprocket holes, pleats across frame
16.	Missing footage
17.	Teeth marks between sprocket holes and on frame
18.	Claw marks between sprocket holes
19.	Film broken across frame in many places
20.	Pleats across frame
21.	Single breaks from sprocket holes to edge of film
22.	Chipped sprocket holes, teeth marks on frame and between sprocket holes
23.	Buckled film
24.	Breaks from sprocket holes toward edge and toward frame
25.	Sprocket hole edge of film snagged at intervals
26.	Nicked in outside corners of sprocket holes
27.	Edges of film pinched
28.	Sprocket hole edge of film shaved off

Methods of Procedure

As a basis for this study, a complete file of damage reports for a full fiscal year was consulted. Separating total from partial damages, the reports were broken down into months and the four sizes of films involved. All the damages for each month were tabulated in a systematic manner, indicating color of the film, amount and location of damage, and the type of damage.

The authors are in the fortunate position personally to have seen and passed judgment on all damages; hence, the descriptions are reasonably uniform.

After all damages were classified according to the descriptions given, each damage type was assigned a code number for ease in handling data. It may be added here that the damage types described in this paper are the major types found.

Results

In Table I are descriptions of the damage types in partial and complete film damages for a full fiscal year. Doubtless, there may be other types of rare damages found in former years, but in the main, this list of 28 damage types adequately describes damaged conditions of the group of films in question. Inasmuch as these damages are given code numbers, it may become necessary to use Table I as a reference point whenever damage-type code numbers alone are used in the discussion.

In Table II is a detailed breakdown of the frequency of damages found in 400-ft films. An analysis of partial damages found at the beginning of films shows that, with the exception of damage types 12, 13, 14, 19, 21, 24 and 25, all other damage types are represented. The total amount of black-and-white film damage amounted to 2,863 ft, whereas 814 ft of color film was damaged. Of the total number of damages found in the beginning of 400-ft films, 23% were in color films. Twenty-two per cent of the total damaged footage was color. Were it not for the high destructiveness of damage type 5, the damaged footage for color film would have been very much less, for in other damage types the average color film damage was usually less than for black-and-white films, which accounted for 40% of the 96 damages at the beginning of 400-ft films.

Table II continues with a detailed analysis of damages found in 400-ft films at various points up to the halfway mark in the film and some distance in from the beginning of the film title. Of black-and-white film, 1,195 ft were damaged, with 258 ft of color film damaged. Of the 80 damages, 22.5% were found in color film. Nineteen per cent of the total damaged footage was color film.

In the portion of the 400-ft film beginning at the halfway point, but not extending to the end of the film, 33 damages were recorded. Table II shows only one of these to be in a color film, with 13 ft, whereas there was a total of 679 ft of damaged black-and-white film.

At the extreme end of 400-ft films, as indicated in Table II a total of 58 partial damages was found. Of the total, 18 were color film damages, or 31% of the total number of the damages. For black-and-white film, 1,225 ft were damaged, with 589 ft of damaged color film or 32.4% of the total damaged footage. Twice as much black-and-white footage was damaged as color film footage.

For 800-ft films, starting at the beginning of film, Table III shows a total of 30 damages, of which 20% or 6 were damages in color films. In black-and-white films, 877 ft was damaged, with 306 ft damaged in color films. This indicates that 25.7% of the damaged footage was in color film. Of the total, black-and-white damaged footage amounted to 2.5 times that of color in 800-ft films, at the beginning of the film.

Table III shows a total of 26 damages in 800-ft films, occurring in that part of the film between the beginning of the

title up to the midpoint of the film. Damage types 6 and 8 were prominent, with 9 damages recorded under damage type 1. Only two damages of color film with a total of 306 ft were recorded. Twenty-four black-and-white films were damaged with a total footage of 411 ft. A high 43% of the total damaged footage was in color film, whereas only 8% of the damages were color films.

In the 800-ft film, from the midpoint on, but not extending to the end, 9 damages were located, 2 of which, or 22%, were in color films. Table III points out that 71 ft of the damage were black-and-white, with 74 ft in color film. Here is again an instance where the destruction of color film seemed to be out of proportion to what one might expect.

Damages at the end of 800-ft films were found to be limited, with two damages of black-and-white films and a total of only 27 ft involved.

One may readily see in Table IV that partial damages in 1,200-ft color film were indeed rare. Comparing only black-and-white in the four portions of the film, we see that there were a total of 5 damages, or 153 ft, at the beginning of the film. A considerable increase is shown in the portion of the film up to

Table II. Analysis of Partial Damages in 400-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
Beginning of Film			
1 B-W*	39	31	
1 C	7	21	
2 B-W	1	21	
3 B-W	1	67	
4 B-W	2	112	
5 B-W	5	23	
5 C	4	126	
6 B-W	3	48	
6 C	4	14	
7 B-W	2	20	
7 C	1	21	
8 B-W	7	60	
8 C	1	6	
9 B-W	2	44	
10 B-W	3	20	
10 C	1	24	
11 B-W	2	26	
11 C	1	14	
15 B-W	1	50	
16 B-W	1	5	
16 C	2	6	
17 B-W	1	135	
18 B-W	1	18	
20 C	1	30	
22 B-W	1	85	
23 B-W	1	65	
26 B-W	1	61	
First 200 Ft			
1 B-W	43	20	56
1 C	8	10	99
3 C	1	4	94
4 B-W	1	6	87
5 B-W	5	8	79
5 C	4	18	73
6 C	1	18	21
8 B-W	4	26	89
8 C	2	28	52
9 C	1	24	168
10 B-W	2	76	8
12 B-W	1	6	18
17 B-W	1	8	124
19 B-W	1	9	6
14 B-W	2	10	23
Last 200 Ft			
1 B-W	18	19	309
1 C	1	13	202
4 B-W	1	12	356
5 B-W	1	3	376
6 B-W	3	12	318
8 B-W	6	39	294
13 B-W	1	17	252
20 C	1	4	223
22 B-W	1	8	218
25 B-W	1	126	224
End of Film			
1 B-W	25	31	
1 C	15	28	
5 B-W	1	117	
6 B-W	3	14	
6 C	2	38	
8 B-W	5	19	
9 B-W	1	50	
11 B-W	2	21	
13 B-W	1	88	
16 B-W	1	18	
20 C	1	93	
21 B-W	1	2	

* B-W = black-and-white; C = color

the midpoint, with 21 damages or a total of 885 ft. Two damages involving 10 ft were recorded from the midpoint on, with 2 damages at the end for a total of 39 ft.

In damages of 1,600-ft films, as outlined in Table V, a total of 22 partial damages was recorded. At the beginning of the film, 4 damages were found for a total of 94 ft. In the portion of the film up to the midpoint, 11 damages were recorded for a total of 2,150 ft. This seems to be an extraordinary amount of damaged footage for only 11 damage cases. From 800 ft on, but 3 damages were found with a total of 39 ft involved. Four damages were located at the end of 1,600-ft films, amounting to 189 ft.

Comparing monthly circulation of films with the number of damages per month, Table VI draws these data out in some detail for 400-ft films. In October, the Audio-Visual Center circulation was 10% of the year's total, with 12% of the year's partial damages and 30% of the total or complete damages falling during this month. In September, with but 7% of the annual circulation during that month, 15% of the year's complete damages were found. February, with the second highest monthly circulation for the year, had 18% of the partial damages as well as the greatest number

Table III. Analysis of Partial Damages in 800-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
...........Beginning of Film...........			
1 B-W*	15	25	
1 C	4	72	
4 B-W	1	326	
5 B-W	1	3	
8 B-W	4	32	
10 B-W	1	8	
10 C	2	9	
16 B-W	1	22	
27 B-W	1	15	
.............First 400 Ft.............			
1 B-W	7	33	174
1 C	2	153	125
4 B-W	2	10	40
5 B-W	2	4	100
6 B-W	5	16	197
8 B-W	5	3	134
10 B-W	2	27	115
17 B-W	1	3	31
.............Last 400 Ft.............			
1 B-W	2	6	630
1 C	2	32	406
6 B-W	1	3	455
8 C	2	5	428
10 B-W	1	23	571
20 B-W	1	33	488
.............End of Film.............			
1 B-W	1		
6 B-W	1		

* B-W = black-and-white; C = color

Table IV. Analysis of Partial Damages in 1,200-Ft Films

Damage Code No.	Total No. of prints	Average footage per damage	Point at which damage starts
...........Beginning of Film...........			
1 B-W	3	35	
3 C	1	25	
4 B-W	1	18	
5 B-W	1	30	
.............First 600 Ft.............			
1 B-W	9	24	279
1 C	1	3	273
4 B-W	3	5	200
6 B-W	3	72	222
7 B-W	1	67	318
8 B-W	2	159	466
9 B-W	1	3	484
10 B-W	1	47	135
.............Last 600 Ft.............			
1 B-W	1	4	1,125
4 B-W	1	6	837
.............End of Film.............			
6 B-W	1	30	
21 B-W	1	9	

* B-W = black-and-white; C = color

Table V. Analysis of Partial Damages in 1,600-Ft Films

Damage Code No	Total No. of prints	Average footage per damage	Point at which damage starts
...........Beginning of Film...........			
1 B-W*	2	31	
6 B-W	1	20	
16 B-W	1	12	
..............First 800 Ft..............			
1 B-W	6	125	322
6 B-W	2	280	49
8 B-W	1	10	576
9 B-W	2	415	280
..............Last 800 Ft..............			
1 B-W	2	10	1,426
8 B-W	1	19	1,083
..............End of Film..............			
1 B-W	2	65	
6 B-W	2	29	

* B-W = black-and-white; C = color

Table VI. Percentage Analysis of Partial and Complete Damages of 400-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	5	1.86	5	2.04	0	0
Aug.	813	1.65	5	1.86	5	2.04	1	2.50
Sept.	3,825	7.76	23	8.57	20	8.16	6	15.00
Oct.	5,347	10.85	33	12.31	30	12.24	12	30.00
Nov.	5,528	11.23	23	8.57	23	9.30	5	12.50
Dec.	4,158	8.45	27	10.07	25	10.20	2	5.00
Jan.	4,844	9.14	15	5.22	15	6.12	3	7.50
Feb.	5,853	11.88	53	19.77	45	18.36	1	2.50
Mar.	7,111	14.44	41	15.29	38	15.05	4	10.00
Apr.	5,692	11.34	22	8.20	18	7.37	3	7.50
May	3,504	7.12	21	7.83	20	8.16	3	7.50
June	1,253	2.54	0	0	0	0	0	0
Total	49,271		268		244		40	

Table VII. Percentage Analysis of Partial and Complete Damages of 800-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	0	0	0	0	0	0
Aug.	813	1.65	0	0	0	0	1	11.11
Sept.	3,825	7.76	7	10.01	6	10.00	0	0
Oct.	5,347	10.85	7	10.01	4	6.66	1	11.11
Nov.	5,528	11.23	9	13.07	8	13.33	1	11.11
Dec.	4,158	8.45	3	4.34	3	5.00	2	22.22
Jan.	4,844	9.14	4	5.80	4	6.66	2	22.22
Feb.	5,853	11.88	8	11.59	7	11.66	0	0
Mar.	7,111	14.44	15	21.73	12	20.00	2	22.22
Apr.	5,692	11.34	8	11.59	8	13.33	0	0
May	3,504	7.12	7	10.01	7	11.66	0	0
June	1,253	2.54	1	1.45	1	1.66	0	0
Total	49,271		69		60		9	

of films with more than one damaged section per film. Remarkably, only 2.5% of the year's complete damages occurred in February. With 14% of the year's circulation falling in March, 15% of the partial damages occurred along with 10% of the complete damages.

As outlined in Table VII, November proved to be the autumn month for the greatest percentage of partial damages in 800-ft films, namely, 13%. For the spring period, March, with 14% of the film circulation, had a very high 20% of the complete damages.

February, with 11% of the film circulation, had 21% of the partial damages and 40% of the year's complete damages for 1,200-ft films. Table VIII shows the greatest amount of partial damages occurring in March, a destructive 25%.

Table IX indicates that during the month of March, 30% of the damages to 1,600-ft films occurred.

Complete or total damages of all

Table VIII. Percentage Analysis of Partial and Complete Damages of 1,200-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	No. of total damages	% of total damages
July	1,343	2.72	0	0	0	0	0	0
Aug.	813	1.65	4	12.50	1	3.57	0	0
Sept.	3,825	7.76	2	6.25	2	7.14	0	0
Oct.	5,347	10.85	2	6.25	2	7.14	1	20.00
Nov.	5,528	11.23	4	12.50	4	14.28	1	20.00
Dec.	4,158	8.45	3	9.37	2	7.14	1	20.00
Jan.	4.844	9.14	1	3.12	1	3.57	0	0
Feb.	5,853	11.88	6	18.75	6	21.42	2	40.00
Mar.	7,111	14.44	7	21.87	7	25.00	0	0
Apr.	5,692	11.32	3	9.37	3	10.61	0	0
May	3,504	7.12	0	0	0	0	0	0
June	1,253	2.54	0	0	0	0	0	0
Total	49,271		32		28		5	

Table IX. Percentage Analysis of Partial and Complete Damages of 1,600-Ft Films Distributed Each Month of a Fiscal Year

Mo.	Films circulated	% of films circulated	No. of damaged sections	% of damaged sections	No. of films with partial damages	% of partial damages	% of total damages
July	1,343	2.72	0	0	0	0	No total damages of 1,600-ft. films
Aug.	813	1.65	0	8.69	0	0	
Sept.	3,825	7.76	2	8.69	2	9.52	
Oct.	5,347	10.85	3	13.04	3	14.28	
Nov.	5,528	11.23	2	8.69	2	4.76	
Dec.	4,158	8.45	0	0	0	0	
Jan.	4,844	9.14	1	4.34	2	4.76	
Feb.	5,853	11.88	4	17.38	4	19.04	
Mar.	7,111	14.44	7	30.43	7	33.32	
Apr.	5,692	11.34	2	8.69	2	9.52	
May	3,504	7.12	2	8.69	1	4.76	
June	1,253	2.54	0	0	0	0	
Total	49,271		23		21		

films are listed in Table X. With a fair number of color 800-ft films in the library, it is unusual that no complete damages occurred. Yet, with the relatively few 1,200-ft color films in the library, two of these received complete destruction.

Table X. Analysis of Total Damages of Films Circulated During the Fiscal Year

Damage Code No.	Total No. of prints	Damage Code No.	Total No. of prints
..............400-Ft Films..............			
1 B-W*	11	9 B-W	1
1 C	1	10 B-W	4
2 B-W	1	10 C	2
4 B-W	8	11 B-W	1
5 B-W	1	13 B-W	1
5 C	4	14 B-W	1
6 B-W	1	24 B-W	1
8 B-W	2		
....800-Ft Films..		..1,200-Ft Films...	
1 B-W	3	1 B-W	1
5 B-W	1	4 C	1
6 B-W	1	14 B-W	1
7 B-W	1	17 B-W	1
8 B-W	1	28 C	1
9 B-W	1		
10 B-W	1		

* B-W = black-and-white; C = color

Conclusions and Comments

The damage of teeth marks on sound track is no longer as serious as in former years. This may be due to the decreased use of silent projectors or the amount of training given to projectionists. Attempts have been made to include leaflets with film shipments warning the user of the consequences of threading sound film into silent projectors.

Were it not for our constant practice of keeping each film provided with a 5-ft leader and credit title of appropriate length, the reported damages would be much more numerous. On many occasions, various films were saved from damage by the fact that the leader and credit title served as the necessary margin of warning to the operator to stop the machine when the film did not feed correctly.

Evidence seems to support our contention that the training of projectionists is not done systematically. It appears that every year October and February are the periods of greatest relative film damage. During these months new operators are assigned to serve as projectionists. Many damages suggest that the operator did not understand the proper threading of film. Failure of proper loop formation, for instance, accounted for many of the numerous damages at the beginning of films. It is deemed advisable to assign to each projector one 100-ft roll of practice film, so that each projectionist has an opportunity to practice prior to the use of the films. It has been our policy to make available to all users of our films such a practice reel whenever requested and at no cost.

On the basis of total number of films circulated, it is impossible to predict with any great degree of accuracy how many damages to expect during a given month. Table VI, which contains the percentage analysis of damages for 400-ft films, points this out clearly. If the damages in other years were analyzed in the same manner, trends in damage patterns might be shown.

Although 800-ft films comprised approximately 26% of the prints in our film library, only 17% of the partial damages and 17% of the complete damages were in 800-ft films, which helps to support our belief that these require proportionately less maintenance time.

The damaged footage of color film seems higher than one would expect. Probably color films were more heavily booked on the average, hence the chance for damage was greater. This matter would be greatly clarified if exact figures were available relative to the number of color films distributed each month as compared with black-and-white films.

A New Theater Sound System

By B. Passman and J. Ward

A fully integrated sound system designed to meet the needs of regular and drive-in theaters, having power requirements ranging from 20 to 280 watts, features standardized chassis and cabinet design, interchangeable power amplifiers and a plug-in preamplifier located in the soundhead. Use of modern circuit techniques and conservative rating of all components afford reliability and rated performance under all conditions.

THE PERFORMANCE of the system to be described meets or exceeds the specifications recommended by the Motion Picture Research Council.[1] Many operational and service features are provided as a result of considerable experience in the field of theater equipment design.

For all indoor theater systems a standard four-section cabinet contains one or two power amplifiers, a monitor amplifier, a speaker network and an exciter lamp power supply. Preamplifiers are located in each soundhead and in a nonsynchronous control cabinet. A 500-ohm line couples the power amplifiers to the preamplifiers through control cabinets which house the sound change-over switches and volume controls. A control cabinet is mounted on the front wall adjacent to each soundhead.

For the larger drive-in theater systems the standard four-section cabinet contains three or four power amplifiers, each of which feeds one group of In-A-Car Speakers. Single-section cabinets are used for the smaller drive-in systems requiring only one or two power amplifiers. Preamplifier, control and soundhead equipment is similar to that which is provided for indoor theaters with the exception that the exciter lamps are a-c-energized from individual transformers supplied with each soundhead. All systems employing more than one power amplifier are provided with control switches which permit isolation of an inoperative amplifier for service or removal, while maintaining emergency operation with the remaining amplifier or amplifiers.

The standard cabinets are equipped with sliding chassis mounts so that chassis may be withdrawn and inverted while in operation (Fig. 1). Each chassis is provided with a single harness, which is connected by means of self-locking lugs and clamp screws to an accessible terminal board mounted at the front of the cabinet. The chassis are interchangeable and may be disconnected

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Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by B. Passman, International Projector Corporation, Bloomfield, N.J., and J. Ward, General Precision Laboratory, Pleasantville, N.Y.

Fig. 1. Chassis inverted for service.

and removed from a cabinet in a few minutes with the aid of a screw driver only.

Soundhead and Preamplifier

Figure 2 shows the soundhead from the operating side. The scanning system layout provides for easy threading and cleaning and the complete assembly is attached to the main frame by means of vibration insulating mounts. Flutter content is held to less than 0.15% as recommended by the Motion Picture Research Council[1] by means of the familiar rotary stabilizer. Dual exciter lamps are mounted on a turret so that a stand-by lamp may instantly be set in position by operation of a convenient lever. An optical system of the stereopticon type, used in conjunction with a vertical filament exciter lamp (9-volt, 4-amp), combines ease of adjustment with exceptional uniformity of sound track illumination.[2] A gas-filled red-sensitive photoelectric cell, type 930, is normally supplied but the blue-sensitive vacuum cell, type 929, may be used without changes if desired.

The gearbox is unit constructed and oil filled to insure precision, quiet operation and long life. Ball bearings are used throughout, and the complete

gearbox is easily removable as a unit. A ¼-hp heavy-duty induction motor provides adequate reserve power and the desired slow starting characteristic is insured by means of a heavy flywheel. A conveniently located brake lever enables the motor to be stopped quickly in the event of film breakage.

A two-stage preamplifier ruggedly built on a plug-in chassis is located in a separate closed compartment at the rear of the soundhead. In this location the amplifier is adequately shielded and protected from dirt and oil. Standard components and regular type 6J7 tubes are used and all connections are made by means of a rugged plug having large-diameter locating pins and silver-plated contacts. Figure 3 is a circuit schematic. In order to stabilize performance and reduce harmonic distortion and microphonic noise, approximately 20 db of inverse feedback is applied from the cathode of the second stage to the input grid. Normal output from a fully modulated sound track into 500 ohms is 6 milliwatts with total harmonic distortion of less than 0.25%. At 60 milliwatts output, the total harmonic distortion is less than 1%. The relative frequency response of the amplifier is within ± 1 db from 50 to 10,000 cycles, and the maximum noise level is 70 db below 6 milliwatts. No noticeable microphonic noise is apparent even when the amplifier is deliberately rattled inside its housing. R14 is a preset gain control with a range of 10 db which is provided for balancing the output from individual soundheads. Low-frequency warping is accomplished by selection of values for R1 and C1.

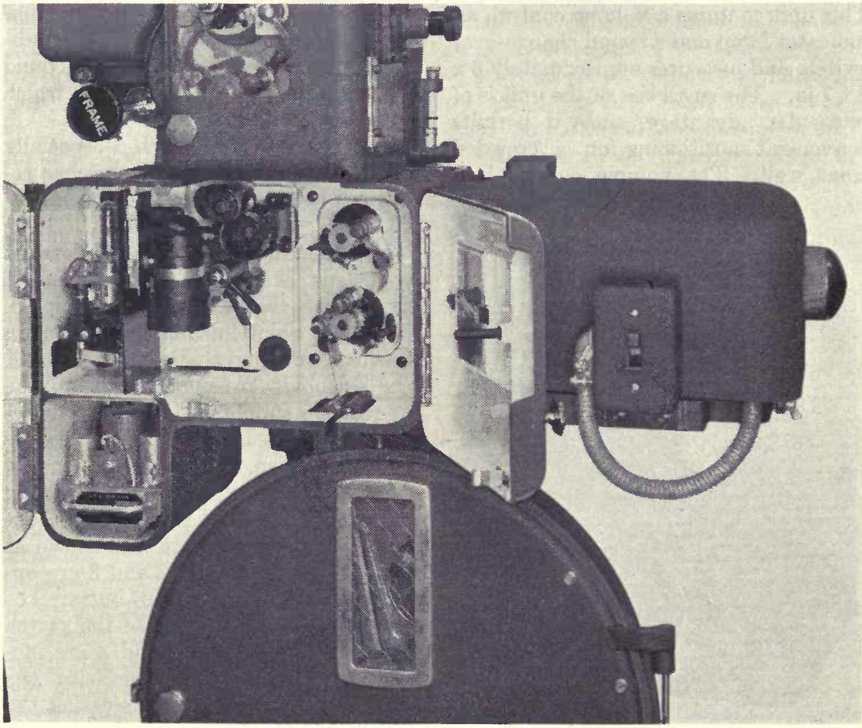


Fig. 2. Soundhead, operating side.

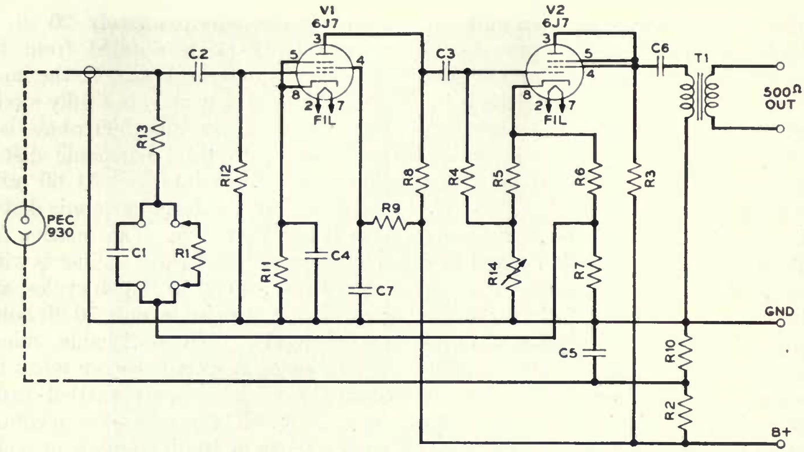


Fig. 3. Preamplifier schematic.

Sound Change-over

Figure 4 shows the control cabinet which is used with each soundhead. This unit contains a volume control, an indicator lamp and a sound change-over switch, and measures approximately 6 x 6 x 7 in. The small size of the unit is of particular advantage, since it permits convenient positioning on a crowded front wall. The volume control is a conventional bridged-T type attenuator having silver contacts and twenty detented 2-db steps, and is connected in the 500-ohm line between the preamplifier and the power amplifiers. The indicator lamp is connected to the sound change-over switch to show which soundhead is in operation.

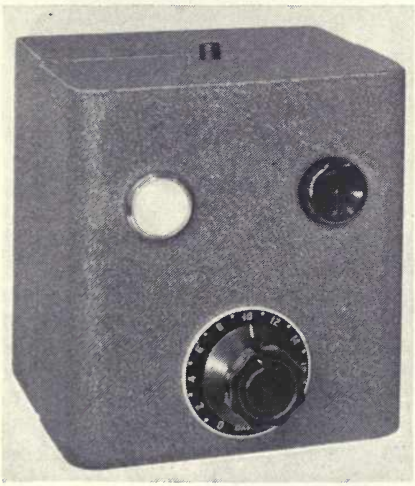


Fig. 4. Sound change-over cabinet.

The change-over switch is specially designed to eliminate all mechanical linkages between projectors without introducing complicated wiring. The switch is manually closed and latched by means of a push button, but is opened by the action of a solenoid. Figure 5 is a simplified circuit schematic showing two sound change-over stations. The solenoids are energized from the 6.3-volt a-c supply to the preamplifiers and all contacts are directly operated by the push button. Contacts numbered 4 and 5 and 7 and 8 are mechanically latched in the closed position upon operation of the push button as shown at station 1. Contacts 1, 2 and 3 are operated by the push button, but are not latched. Upon operation of the switch at station 2, contacts 2 and 3 are momentarily closed, thus energizing the solenoid at station 1 and releasing the switch. At station 1, contacts 7 and 8 will open and 6 and 7 will close, thus

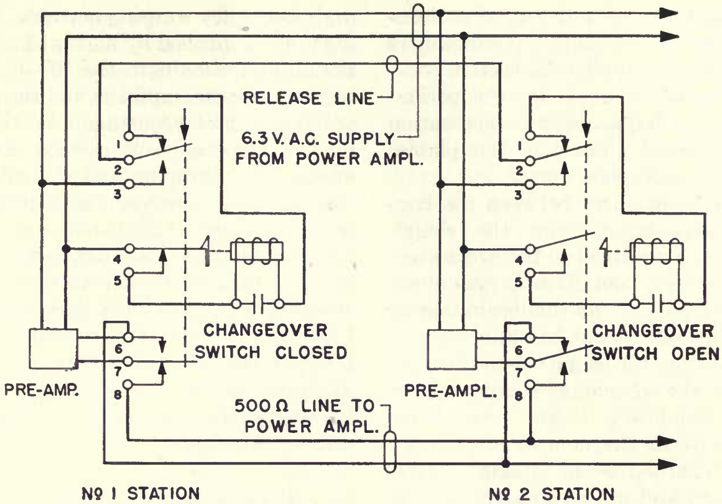


Fig. 5. Sound change-over schematic.

disconnecting station 1 preamplifier from the 500-ohm line and shorting its output. At station 2, contacts 6 and 7 will open and 7 and 8 will close, thus connecting preamplifier 2 to the 500-ohm line. This assures freedom from "break through" from the unused soundhead. Contacts 4 and 5 are provided so that only the solenoid of a latched switch may be energized; this means that however many sound change-over stations are involved, the total current required for changeover is limited to that necessary for one solenoid.

The system is completely silent in operation and entirely reliable. Even in the event of failure of the solenoid system the signal from the "incoming" projector will be connected to the power amplifiers, since the switch contacts are manually closed. Under these conditions the signal from the "outgoing" projector may be disconnected from the power amplifiers by manual release of the latch or by operation of the associated volume control. It will be noted that three lines only are required between stations; of these the 6.3-volt pair and the 500-ohm pair are required for the preamplifiers. The single release line, therefore, is the only additional wire necessary for sound changeover. Furthermore, a third projector or any number of stations may be added by extending the three lines shown without additional complicated wiring. Normal system interconnections also include B plus and ground wiring for the preamplifiers; these connections are not shown since they are not associated with the operation of the change-over switches.

Nonsynchronous Input

In order to provide for convenient connection and control of the nonsynchronous inputs, a separate plug-in preamplifier is provided and is connected to the 500-ohm line through a volume control and change-over switch in the same manner as the soundhead preamplifiers. The additional preamplifier and controls are mounted in the cabinet shown in Fig. 6. The use of a separate plug-in preamplifier and cabinet serves three purposes:

1. A spare preamplifier, warmed up and ready for use, is instantly available as an emergency replacement for the soundhead preamplifiers.

2. A convenient and accessible location is provided for testing preamplifiers with all power supplies connected.

3. Provision is made for the permanent connection, necessary equalization and convenient control of the phonograph and microphone inputs.

Sound change-over between the nonsynchronous inputs and the soundheads is accomplished in the same manner as between soundheads, thus eliminating "juggling" at the beginning or end of the show or at the intermission, and ensuring the same silent nonsynchronous change-over as is obtained between soundheads. The installation and control of the nonsynchronous inputs is regarded as an integral part of the system and not as something to be added at the last moment by the installation engineer.

Also located in this cabinet is the high-frequency warping network. Warping is accomplished by means of conventional filter circuits in the 500-ohm line between the preamplifiers and the power amplifiers, and adjustment of the frequency response over a wide range is effected by strapping and the substitution of capacitors and resistors on the terminal board which is mounted beside the preamplifier. Standard adjustment is in accordance with the Motion Picture Research Council's "Standard Electrical Characteristic for Theatre Sound Systems,"[1] and in addition to the usual variable "roll-off" provision is made for increasing the response in the 3000- to 4000-cycle region.

Power Amplifiers

To provide for regular and drive-in theater sound systems requiring from 20

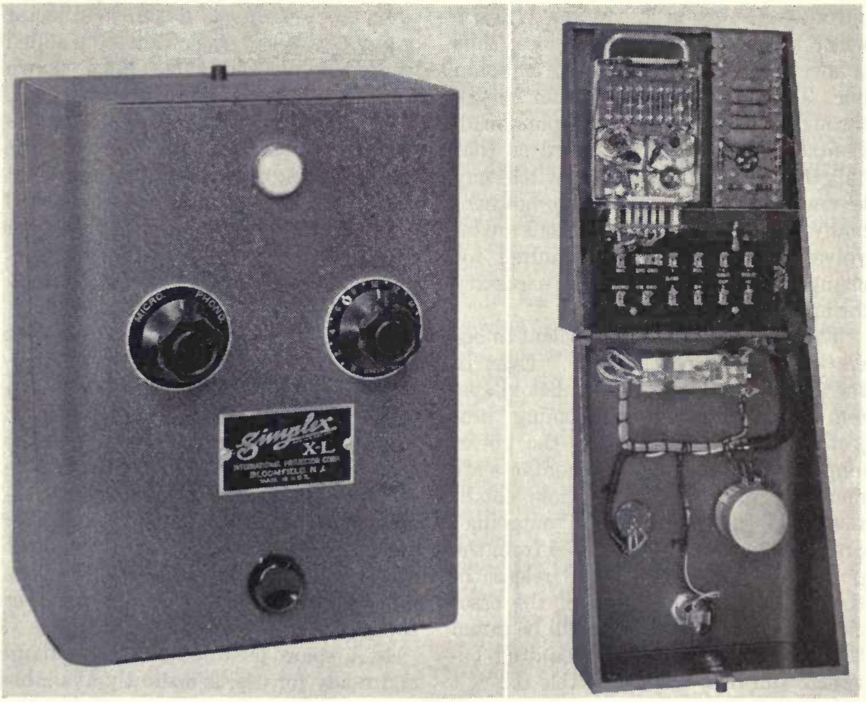


Fig. 6. Nonsynchronous input control cabinet.

to 280 watts, two power amplifiers have been designed. The amplifiers are constructed on the same standard chassis and are, therefore, interchangeable. Figure 7 is a schematic diagram of the larger amplifier. For regular theater use this amplifier is conservatively rated at 60 watts with less than 2% total harmonic distortion from 50 to 5,000 cycles. For drive-in theater use the amplifier is rated at 70 watts since maximum power output at very low frequencies is not required for the operation of In-A-Car speakers. Type 807 tubes are operated in push-pull AB2 with fixed bias and a regulated screen supply. Voltage regulator tubes V6 and V7 are used to control the screen voltage and a selenium rectifier CR1 and CR2 provides the bias voltage. The 807's are driven by a low-impedance source consisting of push-pull cathode followers V3. In this manner the output tubes are operated strictly within design center ratings and maximum power is assured under all conditions.

The phase inverter is of the "floating-paraphase" type, employing double triodes V1 and V2 connected in "cascode" (plate-to-cathode coupled). This arrangement provides the necessary gain and voltage swing with but one coupling circuit, thus permitting the use of negative feedback around the entire amplifier. The use of considerable negative voltage feedback from the secondary of the output transformer T2 to the cathode of the first tube VI would normally result in an exceptionally low internal output impedance. For optimum performance of the speaker system, however, the internal impedance of the amplifier is increased to approximately 0.7 times the speaker load impedance by the application of some negative current feedback which is obtained from the current flowing through the secondary of the output transformer and the resistor R34. The total inverse feedback of approximately 12 db reduces harmonic distortion and stabilizes performance; relative frequency response is within ± 1 db from 50 to 10,000 cycles and the noise level is 35 db below 6 milliwatts.

The amplifier input transformer T1 is designed to bridge across a terminated 500-ohm line and full output is obtained when the level in the 500-ohm line is −20 db with reference to 6 milliwatts (0.173 volts). Since all gain-control and warping adjustments are effected in the preamplifiers and the 500-ohm line, power amplifier gain and frequency response is standardized and amplifiers may therefore be operated in parallel without balancing or adjustment of any kind. Full rated power for regular theater systems employing dual amplifiers is therefore assured. For drive-in systems employing multiple amplifiers the inputs are connected in parallel but each amplifier output feeds one group of speakers.

The smaller power amplifier differs from the 70-watt amplifier only in the following respects:

1. Type 6L6 tubes operating in push-pull AB1 are used in the output stage.
2. Voltage regulator tubes are not necessary and only one rectifier tube is required.
3. A single twin triode serves for the "floating paraphase" phase inverter.

All features of the larger amplifier are retained and the performance is identical, except for the power output which is 20 watts with less than 2% total harmonic distortion from 50 to 5,000 cycles.

Exciter Lamp Power Supply

The exciter lamp power supply is constructed on a standard chassis and is mounted in the four-section cabinet in the same manner as the power amplifiers. The power supply provides 9 volts 8 amp of direct current so that only a single unit is required for a normal two-projector system.

A voltage-regulating transformer is used to ensure constant exciter lamp current and hence to minimize the effects of varying line voltage on system

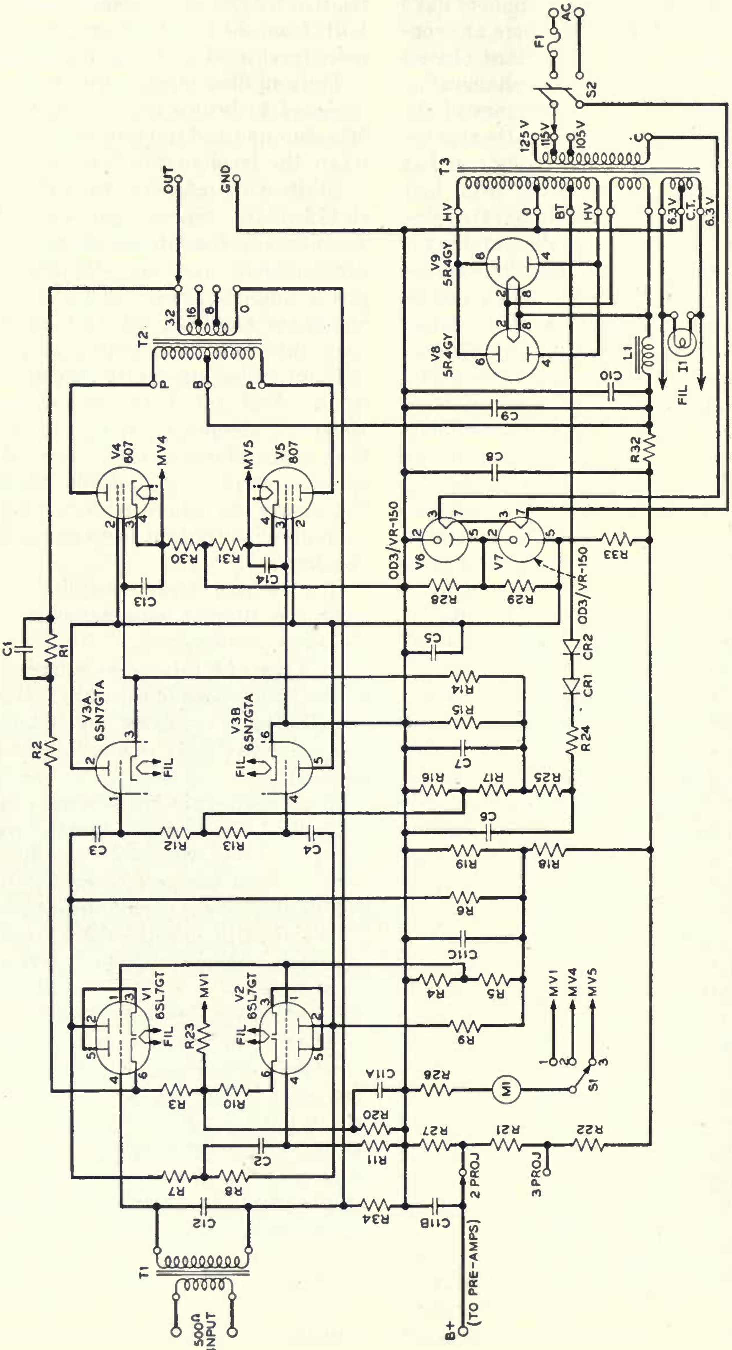


Fig. 7. Power amplifier schematic.

gain. For reliable operation with freedom from maintenance, a bridge-type selenium rectifier is used; extended life tests indicate that conservatively rated high-quality selenium rectifiers may be expected to operate satisfactorily for the normal life of the equipment. A two-stage L-C filter results in a ripple content of less than 5 millivolts which, with 9-volt 4-amp exciter lamps, does not contribute to the system noise level.

Individual preset controls are provided for setting and balancing the supply to each exciter lamp. Current-type relays in series with each lamp are arranged to connect a dummy load resistor to the power supply in the event that either exciter lamp burns out. A standby switch provides for emergency operation of the exciter lamps from alternating current in case of failure of the rectifier or filter circuits.

For drive-in systems operating with In-A-Car speakers a d-c exciter lamp supply is not necessary. Exciter lamps having heavier filaments (10-volt 7.5-amp) are supplied with alternating current from transformers associated with each soundhead.

Stage Speaker Equipment

To ensure optimum over-all performance, new speaker equipment has been designed and engineered by Altec Lansing as an integral part of the sound system. Figure 8 shows the arrangement of a large speaker system having six low-frequency and four high-frequency driver units. Careful attention to the physical layout of the low-frequency horns has resulted in a remarkable improvement in the uniformity of phasing of the high- and low-frequency units over a wide angle and throughout the entire seating area. Furthermore, the design is entirely flexible since identical low-frequency units may be stacked to accommodate the larger systems.

The high-frequency driver units incorporate a newly developed "acoustic filter cap" which is located immediately behind the diaphragm. In electrical analogy this acoustic filter serves as a condenser in series with the high-frequency voice coil, and hence complements the function of the electrical dividing network below 500 cycles. This acoustic filter contributes appreciably to the smoothness of the high-frequency reproduction, and in particular, improves the over-all response characteristic in the crossover region. This development also provides a safety factor which allows the high-frequency units to handle greater power without danger of damage to the diaphragms.

A single standard electrical dividing

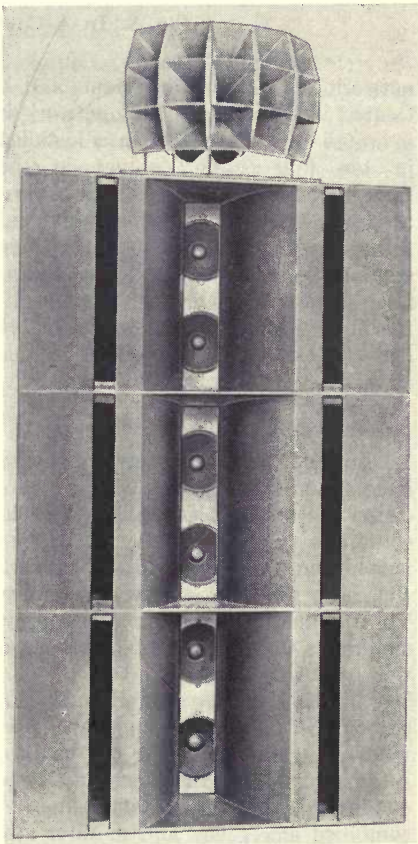


Fig. 8. Stage speaker equipment.

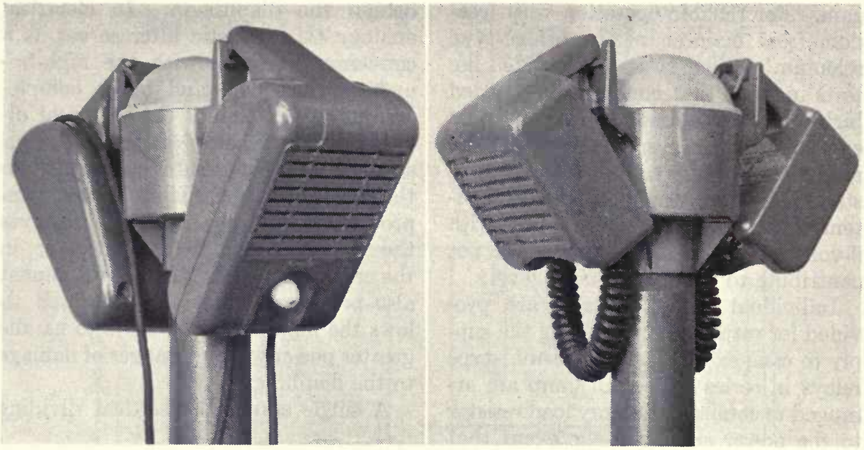


Fig. 9. In-A-Car speaker equipment.

network is used for all systems and is located in the booth. This network is mounted on a chassis which is installed in the four-section cabinet in the same manner as the power amplifiers. Switches are provided for individual control of the high- and low-frequency speakers so that either unit may be isolated in case of emergency. Test facilities in the form of dummy load resistors and a jack are also provided on this chassis.

Monitor Equipment

Also mounted on the network chassis is the monitor amplifier and its associated controls. This amplifier is a self-contained unit which may be disconnected and removed from the network chassis by means of a screw driver only. The amplifier has its own power supply, employs a 6L6 output tube with negative feedback, and is rated at 4 watts. The unit is therefore entirely independent of the power amplifiers and provides adequate power for the monitor speaker under all conditions and without loss of power on the stage line. A combined emergency and monitor amplifier power switch is arranged so that the monitor speaker is operated directly from the stage line when the monitor amplifier switch is in the "off" position.

The monitor speaker is mounted in a reflex-type cabinet and the over-all performance is such that the equipment is of real value for trouble shooting and monitoring sound quality.

Ramp Control and In-A-Car Speakers

A ramp control cabinet is provided with all drive-in systems; each ramp is connected to the power amplifiers through a switch so that the projectionist may immediately isolate a failure, such as a short in the underground wiring. The effect of such a failure may, therefore, be limited to a small group of speakers, thus preventing a general loss of sound throughout the theater. A preset dummy load resistor is connected to each switch and is adjusted to match the associated ramp impedance at the time of installation so that a reasonably constant load is presented to the power amplifiers under all conditions.

Each ramp control panel is provided with twelve ramp switches and the cabinet accommodates one or two panels, as required. One of the control panels, used on all systems, is provided with a

monitor volume control, a monitor selector switch and a line matching transformer. The switch permits selective monitoring of the larger systems having from two to four power amplifiers, each feeding a group of ramps. The use of a monitor amplifier in this application is unnecessary.

In-A-Car speakers (Fig. 9) are available in two sizes, one having a 3½-in. speaker unit and the other a 4-in. speaker unit. Both types have rugged die-cast housings finished in baked enamel, and adequately weatherproofed; straight or coiled cords are optional. Volume control is by means of a rheostat and a full off position is provided. The units are designed to withstand considerable patron abuse.

The coupling unit is common to both types of speaker and contains a vacuum impregnated line transformer, a 28-volt lamp and the necessary rugged terminals for the heavy ramp cable connections. The main body is die cast, and has the same durable finish as the speakers. All electrical components are mounted on a terminal panel which is retained vertically between slots in the coupling unit casting. A translucent plastic dome covers the casting and provides a diffused glow which facilitates return of the speakers to the coupling unit at the end of the show. The dome may also be used to indicate ramp and car location numbers. In addition to providing illumination for the dome, the lamp is positioned so that a circle of light is projected onto the ground in front of the post. This combined post-and-dome lighting has been found to be most effective in protecting the equipment from accidental damage.

Installation procedure is simplified by shipping the coupling unit as parts instead of complete assemblies. The casting is first mounted on the post, then the terminal panel is dropped in place and all ramp and speaker connections made. After tests, the plastic dome is placed on the casting and retained by a special locking device.

Conclusion

Simplex XL sound equipment is already in production and systems have been installed in many indoor and drive-in theaters. Initial reports received from service and installation engineers, projectionists and exhibitors highly commend the flexibility of installation, operational features and high quality of sound reproduction.

References

1. "Standard Electrical Characteristics for Theatre Sound Systems," Technical Bulletin of the Motion Picture Research Council, Inc., April 20, 1948.
2. F. E. Carlson, "Properties of lamps and optical systems for sound reproduction," *Jour. SMPE*, vol. 33, pp. 80–96, July 1939.

The Cooling of Film and Slides in Projectors

By Hugh McG. Ross

A heat-absorbing filter is of primary importance for cooling film or slides, and experimental results are given of the performance of various types. A good filter, combined with a more powerful lamp, allows the screen illumination to be doubled without affecting the film. A study of the heat flow within the film during exposure leads to estimates of the efficacy of methods of film cooling which may be used in the future. The theory of cooling slides shows that best results are given by blowing air at very high velocities across the slide, to remove the "blanket" of stagnant air adhering to the surfaces. A practical slide cooler is described, and its performance figures given.

In virtually every projector the designer and users are faced with the problem of the heating of the film or slide in the gate. This is particularly severe with high-power theater projectors or process projectors used in film studios for front- or rear-projection shots, or when the output of substandard moving or strip-film projectors is increased. In the most powerful of present-day projectors, the heating of the film is the limiting factor, and for projectors to be made with greater light output it will be necessary to use some method of reducing the heating effect. There are two ways of tackling the problem: the first is to reduce the amount of heat at the gate by filtering out unwanted radiation, and the second is the cooling of the film or slide in the gate.

Reprinted by permission of the Editor of *British Kinematography*,[1] in a shortened form prepared by the author, Hugh McG. Ross, formerly of J. Arthur Rank Productions, Ltd., Pinewood Studios, Buckinghamshire, England, now with the Research Laboratories of Elliott Brothers (London), Ltd., Borehamwood, Hertfordshire, England.

Filtering of Radiation

The film or slide is heated by the absorption of the radiant energy in the light beam. This absorption takes place in the silver or dye image, only a negligible amount being absorbed by the base material.[2] The wavelength of the energy which is absorbed is of no consequence—visible and invisible radiation both contributing to the heat—and it is therefore possible to obtain a marked reduction in the heating by filtering out the radiant energy of wavelengths which do not contribute to the final visual or photographic effect. Removal of the infrared radiation is the most important, although it is sometimes of value to remove also the ultraviolet radiation emitted by the high-intensity arc.[3] This has to be done, however, without altering the color of

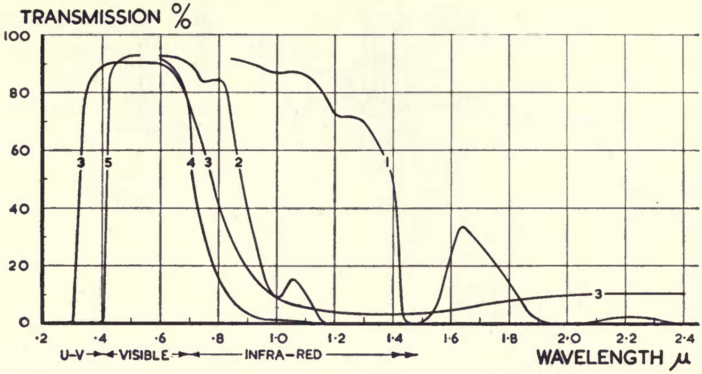


Fig. 1. Transmission curves for various filters for absorbing unwanted infrared or ultraviolet radiation.

Curve 1, water 0.2 cm thick, in glass cell; *Curve 2*, water 5 cm thick, in glass cell; *Curve 3*, Chance's ON20 glass, 0.2 cm thick; *Curve 4*, aqueous solution of ferrous ammonium sulfate, 52 gm per liter, 5 cm thick, in glass cell; *Curve 5*, aqueous solution of orthonitrobenzoic carbonate.

the transmitted light and also with the minimum reduction of the useful light.

Heat-Absorbing Filters. Figure 1 shows the absorption curves of some typical infrared filters. It will be seen that water,[4] even in a very thin layer, is virtually opaque to radiation above 2.35 microns (1 micron = 1 μ = one-thousandth of a millimeter). This is of particular value in keeping cool the lenses and other parts of the optical systems, for crown glass begins to absorb quite heavily at longer wavelengths than this.

The most efficient infrared filter is provided by ferrous sulfate or ferrous ammonium sulfate dissolved in water. The addition of a few drops of sulfuric acid makes the solution more stable. A convenient way of preventing the formation of air-bubbles on the windows of the cell is to add a few drops of detergent or wetting-agent, which prevents the released air from adhering to the windows. A solution of the strength shown, when in a cell 5 cm thick, has a very pale blue-green color, due to slight absorption of the deep-red part of the visible spectrum, but for most applications this is hardly visible.

Perhaps the most convenient infrared filter is provided by type ON20 heat-absorbing glass made by Chance Bros.[5] This is almost colorless (the curves of Fig. 1 have been drawn for ferrous ammonium sulfate and ON20 glass filters appearing visually to have the same color) while it absorbs well in the near infrared. Its transmission increases slightly as the wavelength increases and only becomes negligible above 3.4 μ. For many applications this type of filter is suitable, and the heat which it absorbs may be dissipated by natural convection to the air, or the glass may be cooled by blowing air on it.

Combined Heat-Absorbing Cell and Lens. It is probable, however, that the most suitable infrared filter for practical use in a high-power projector is a combination of a thin layer of water with a sheet of ON20 glass. This absorbs well in the near infrared, provides full protection to the lenses and is reliable and stable in use. Figure 2 shows diagrammatically such a filter combined with the first condenser lens of a process projector.[6] The arc runs at 300 amp with a 16-mm positive carbon,

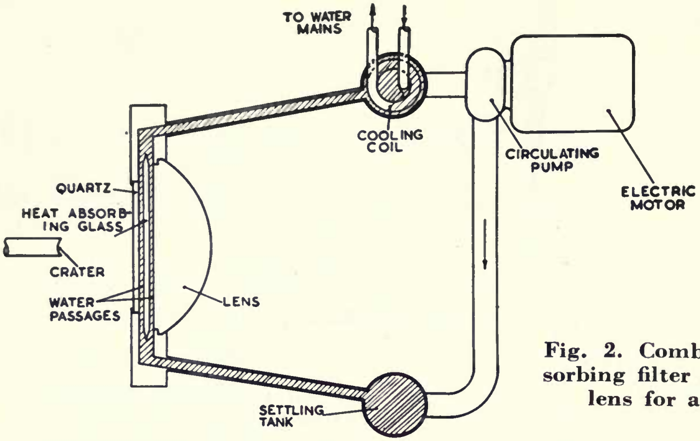


Fig. 2. Combined heat-absorbing filter and condenser lens for a projector.

and 2¾ in. away from this is the front window of the cell 5¼ in. in diameter. This window is made of quartz in order that it may readily withstand the heat of the arc and its flame. On the other side of the quartz there is a narrow water channel, the water being constantly circulated by a pump and motor. The efficiency of cooling the quartz, and the whole front metal plate of the cell facing the arc, is so good that after running the arc at 300 amp for 30 min it is possible to switch off, open the arc door and immediately hold one's hand against the quartz. A further consequence is that the cool quartz window is relatively little damaged by spatter from the arc, and being quite easily replaced, it acts instead of a spatter glass.

The light, after passing through the quartz and first water channel, passes through a sheet of ON20 glass and into a second water channel. The water channels serve the double purpose of cooling the ON20 glass, and also contributing to the filtering of the light. In particular, the first water channel absorbs much of the infrared radiation, thereby reducing the amount which the ON20 glass has to absorb.

If only a heat-absorbing cell were required, the farther window could be made of optical glass. But in this present example the light next passes into the first condenser lens of the optical system. Because the filter has removed the radiation of wavelengths which might be absorbed by the glass, the lens does not get unduly hot and it is therefore made of crown glass for best optical performance. Similarly, the other lenses of the system are not heated seriously.

Only a small quantity of distilled water is circulated continuously around this cell, and the heat which passes into it is removed by a simple heat exchanger comprising a coiled tube through which mains-water is flowing.

The total amount of heat taken up by this cell is 3600 w. About one-third of this is unwanted radiation removed from the light beam, and the remainder is radiated on to the metalwork of the cell which is in the hot lamphouse.

It is estimated that such a cell and lens absorb only 10% of the visible light, compared with an ordinary lens. This is, in effect, recovered by avoiding the use of a separate spatter glass.

Absorption of Ultraviolet Radiation. In Fig. 1 are also shown two absorption curves in the ultraviolet region of the spectrum. Type ON20 glass is not

greatly different from ordinary crown glass in this region. Good absorption may be obtained when using a water-cell by adding orthonitrobenzoic acid and a little sodium carbonate; this solution is colorless.

Luminous Efficiency of Radiation. The relationship between the useful visual quality of light, compared with its unwanted heating effect, is best expressed in terms of the luminous efficiency of the radiation. This represents the amount of visible light (usually measured in lumens) divided by the total heat in the radiation (which may conveniently be measured in watts). It is therefore given in lumens per watt, and when comparing light sources and filters we want this figure to be as high as possible.

For these experiments the visible light was measured with an accurately calibrated visual photometer, and the total radiation was measured by the rate of heating of a blackened metal block, an allowance being made, of course, for its normal cooling to the air.

In Table I the figure for unfiltered tungsten light is experimentally determined, and due to the inaccuracies likely to arise is only approximate. This luminous efficiency of radiation must be distinguished from the over-all luminous efficiency, lumens per electrical watt, which will be somewhat lower. The four-times improvement to tungsten light at 3100 K obtained with 2 mm of ON20 glass may be increased to about six-times by using 3-mm thickness, with slightly more greenish color.

The figure for the unfiltered arc is experimentally determined, and may be subject to some error. An attempt was made to observe only the crater and a small part of the flame above it. In practical terms, the luminous efficiency of the radiation from a mirror-arc projector system is only slightly higher than this, the glass of the mirror giving little filtering.

The improvements to be obtained by filtering the arc are experimentally measured and are reasonably accurate, being also supported by a considerable number of indirect experiments. A two and two-tenths-times improvement over the open arc can be obtained. When modifying a projector by adding a heat-absorbing cell the improvement will not be quite so great.[7]

The negligible absorption of visible

Table 1. Luminous Efficiency of Radiation.

Light source and filter	Luminous efficiency of radiation, lm/w	Absorption of visible light
Tungsten projector bulb, Class A1, 3100 K, 500-w, 110-v	26	—
Tungsten bulb (3100 K) filtered through 2 mm of ON20 heat-absorbing glass	105	12%
Full sunlight	80	—
High-intensity arc, 290-amp, 16-mm positive	85	—
High-intensity arc, filtered through 5 cm water	155	15%
High-intensity arc, filtered through 5 cm water and 2 mm ON20 glass	190	21%
High-intensity arc, through combined heat-absorbing filter and lens	190	0%
White light (5500 K) with no ultraviolet or infrared (0.4–0.7 μ)	220	—

light when using the combined filter and lens is based on the avoidance of the use of a spatter glass.

The last item is the theoretical figure for the maximum luminous efficiency which could be obtained for white light (from a black-body at the optimum temperature, 5500 K), if perfect filtering of the ultraviolet and infrared could be devised.

Employment of Heat-Absorbing Filters. If a projector is causing damage to film by overheating, this may be cured by the addition of a simple heat-absorbing filter. There will, however, be a slight loss of visible light.

It is very much better if the heat-absorbing filter can be incorporated in the projector when it is being designed. In general, the light output of modern projectors is limited by the heating of the film, lamps and carbons being available with a considerable reserve of output. The inclusion of a filter in a projector when it is being designed, combined with a larger lamp, makes possible a doubling of the light output, compared with a projector without a filter. Whenever a projector with very great light output is required, it is inescapable that a filter should be used; it is, furthermore, the easiest way of giving a significant amount of protection to the film, and it should always be used before other methods are incorporated in the projector.

Heating of Film in Moving Projectors

The main heating effect on film in a moving projector is due to the absorption by the emulsion or dye of most of the heat energy in the light beam. The subsequent effects are, however, very different from what happens to anything which is exposed to the light beam for any considerable length of time. Due to the thermal capacity of the piece of film in the gate, the influx of heat cannot raise the temperature instantaneously, and the temperature therefore rises continually throughout the exposing period. Equilibrium is never established; instead, there is a continuous flowing of heat within the film during the exposure. The effect of the thermal capacity of the film and the short time of illumination combine to make it possible to subject film in a moving projector to intensities of light and heat about ten times greater than could ever be attained with stationary film.

Theory of Heating of Film When Exposed to Light. The exact behavior of the heat within the film during exposure has been established by Brian S. Kellett, and the mathematical treatment is given in an appendix to the author's original paper.[1] The light and heat are absorbed by the silver particles in the emulsion layer which, due to its thinness, rises rapidly in temperature. The heat attempts to flow into the base material, but emulsion is a poor conductor of heat, and film base is even worse, and as a consequence the heat does not have time, during the brief exposure period, to travel far into the base.

The temperatures throughout the thickness of the film at the end of the exposure period are sketched in Fig. 3. This refers to a process projector; in a theater projector with a flicker blade on the shutter the heat travels slightly further into the base.[2] The following points arise:

(1) There is only a small drop in temperature through the emulsion layer.

(2) The temperature of the emulsion is much higher than the average temperature of the base. This causes curl or buckling of the film in the gate soon after the beginning of the exposure,[8] and the objective lens has, therefore, to be refocused slightly.

(3) The heat travels only a very short distance into the base during the exposing period and only about 1/1000 in. of the base is heated significantly.

(4) The rise of temperature of the far surface of the base during the exposing

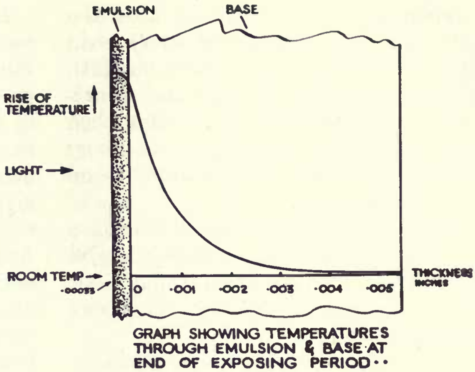


Fig. 3. Enlarged cross-sectional view of film.

The graph shows distribution of temperature within the emulsion and base at end of exposing period in the gate. Only 1/1000 in. of the thickness of the base is heated significantly.

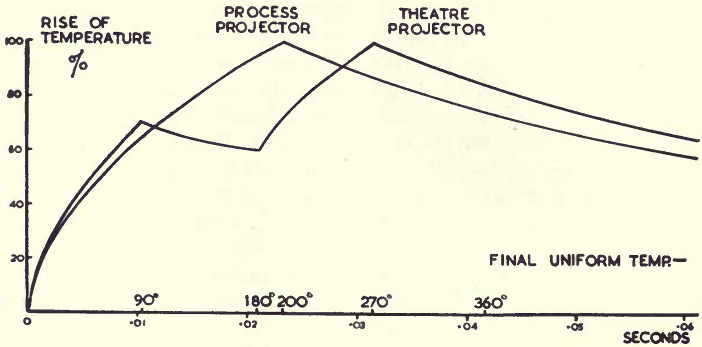


Fig. 4. The heating cycle of film while in the projector gate. The rise of temperature is calculated for the emulsion side of the base. The maximum value reached depends on the light output.

period is about 1/100 of that of the emulsion side of the base.

(5) At the end of the exposing period about one-eighth of the heat is in the emulsion and the remainder is in the base.

(6) It makes little difference whether the light falls on the emulsion side or the base side of the film.

(7) The average density of the print makes but little difference—only practically full whites are significantly cooler.

Temperatures in the Base. Due to the fact that overheating of film first damages the base, rather than the emulsion, it is necessary to consider more particularly the hottest part of the base—that next to the emulsion. Figure 4 shows the temperature of the emulsion side of the base during the exposing cycle. In a theater projector the temperature rises rapidly at first as the light comes on to the particular frame considered, and then falls somewhat as the flicker blade obscures the light — the heat is spreading deeper into the base. During the second exposing period the temperature again rises; in the figure this part of the curve is to some extent estimated. After exposure is completed the heat now in the film (and mainly concentrated in the first thousandth of an inch of the base) spreads throughout the thickness of the base. This spreading is virtually

completed about four frames after the gate (i.e., 4/24 of a second later) when the whole film is at about one-fifth of the maximum temperature previously reached. The whole film then very gradually cools down to room temperature after being wound up on the take-up spool.

The rise of temperature of film in a process projector is also shown in Fig. 4. There is no flicker blade, and a 200° angle of shutter opening has been assumed.

The False Idea of "Gate Temperature." From this argument it is clear that the concept of "gate temperature" has no real meaning, and it is valueless to attempt to define or measure it. Instead, the heating effect in the gate must be referred to the intensity of the radiant flux—the "instantaneous net flux"[2]—which can be expressed, for example, in watts per square centimeter. The effects on the film have been fully studied by Kolb[2] and it is only on the basis of these results and general experience, in conjunction with the knowledge of the luminous efficiency of the filtered light, that it is possible to consider how to increase the light output of moving film projectors beyond the level at which damage now occurs.

Performance of Contemporary Projectors. The foregoing theoretical approach gives the conclusion that the temperature of the emulsion side of the base will rise 100 C (above room temperature) in a typical theater projector giving a light output of 9500 lm. (Light output measured with shutter running; instantaneous intensity of radiant energy at gate, 62 w/sq cm; unfiltered arc light at 95 lm/w; illumination assumed uniform over the gate.) These figures are in reasonable agreement with experience and measurements made on various projectors,[2,7] and suggest that the maximum instantaneous rise of temperature which film will withstand without damage is of this order.

Present-Day Process Projectors. An example of the best performance obtainable now is given by a 35-mm process projector in which every part of the system is developed to its optimum condition. The arc operates at 300 amp with a 16-mm positive, which gives the greatest light intensity consistent with quiet and steady burning. Any increase would result in more noise and greater unsteadiness, or would require a larger carbon with its lower surface brightness. The optical system, incorporating the combined heat-absorbing cell and first condenser lens described earlier, accepts a large proportion of the light from the arc, and this could not be increased very greatly. A relay condenser system ensures uniform illumination over the gate and the objective lenses have an aperture of $f/1.4$. Any change to the optical system to give more light would probably result in nonuniform illumination over the screen or a reduction of definition, particularly since the defocusing effect of film buckling in the gate might become apparent. The light output on the screen is about 50,000 lm, and this is only a little less than the maximum amount of heat which the film will withstand, based on the curve of Fig. 4. (Light measured with shutter not running; instantaneous intensity of radiant energy at gate 58 w/sq cm; well-filtered light at 190 lm/w.) Since each part of this projector is pulling its full weight, it would be difficult to obtain any marked increase in output, although small increases could be made at the price of reduced silence, or less stability and uniformity of illumination or definition, if this could be tolerated in other applications. It is probable, however, that any increase of picture brightness could more easily be obtained by modification to the screens, by silvering, beading or a simple type of lenticular screen.

Air Cooling of Film. With the aim of overcoming the limitation presented by

the overheating of film, consideration may be given to possible methods of cooling film (after filtering the light, of course). Unfortunately, it is the case that air cooling of film in a moving projector does not permit any great increase of light output. It is shown later that there is a theoretical limit to the maximum amount of heat which can be extracted from a surface, such as the emulsion; this is determined primarily by the speed of sound in air, and by the maximum temperature which the film will withstand. Under best conditions, air cooling can remove about 7 w/sq cm, but the acceptable rate of heating of film in a moving projector is about 50 w/sq cm (mean net flux). Air cooling, therefore, in itself can only permit an increase in light output of about 15%,* although Kolb has shown[2] that high-velocity air jets serve a useful, but different, function in helping to hold the film flat in the gate.

Future Developments. Should the need ultimately arise, it is, however, possible to foresee moving projectors with several times as much light output as those of today, perhaps using a "blown-arc" or large arcs and different optical systems. Looking into the future, we may tentatively consider some of the means of preventing the additional light from damaging the film, several of them being well known. In every case, of course, it will be necessary to filter the light.

(1) Using 70-mm film would permit four times the gate area but probably only about three times as much light, since grave difficulties might be experienced with maintaining the film flat in the gate; there would also be much disturbance to printing and processing equipment.

(2) Running the film faster would give it less time in the gate, but reference to Fig. 4 shows that a three-times increase in speed, and therefore three-times film costs, would only permit a two-times increase of light output.

(3) Since the rise of temperature of the rear surface of the base while being exposed is about 1/100 of that of the emulsion side, it will be quite useless to try to reduce the over-all temperature by cooling the rear surface.

(4) It might be possible to surround the gate with a cell with glass windows, filled with liquid, so that the film is immersed in the liquid while it is in the gate. Water is the best cooling medium, and a two and a half-times increase of light could be obtained. Due to the poor conductivity of liquids the temperature distribution through the water would be similar to that shown in Fig. 3 through the film base, except that the heat would penetrate a little further through the water. Even so, only about 0.002 in. thickness of water is absorbing any significant amount of heat. There would be the real complication in drying the film before spooling it, even if another liquid were used.

(5) Cooling with a rapidly moving stream of liquid would be more effective. If glass plates were placed close to the film, to form narrow channels for the cooling fluid which would be pumped through at high velocity, it might be possible to obtain about a four-times increase in the light output.

(6) On several occasions a liquid has been applied to the picture area of the emulsion so that it is evaporated away while in the gate, some of the heat developed in the emulsion providing the latent heat of evaporation instead of heating the base. Only the liquid on the emulsion side of the film assists in preventing damage to the base. The difficulty is that the heat has to travel through the layer of liquid from the

* The relevant experimental results published by Dr. Kolb for film in a moving projector are in the right-hand curve of his Fig. 8 (ref. 2, page 654). This curve shows a maximum increase of light output due to air cooling of 30%, and does not substantiate his claim for a possible increase of 50%.

emulsion to the outer surface of the liquid, where the evaporation to the air is taking place. Due to the poor thermal conductivity, not a great deal of heat is transferred, and instead of evaporating smoothly the liquid might boil off, which might appear on the screen. A high velocity blast of air might assist in preventing this. It is estimated that a two, or perhaps four-times increase of light might be obtained.

(7) Doubling the thickness of the emulsion would only permit a small increase of light, because such a small proportion of the heat is in the emulsion.

(8) Because the basic difficulty arises from the poor conductivity of the film base, some improvement would result if the thermal conductivity or thermal capacity of the base material could be significantly increased. Such a change to the base material appears most unlikely.

It may be concluded that there are several ways in which the light might be increased about four times above the present maximum (after filtering), but each would introduce severe practical difficulties. Even by a combination of the methods at present foreseen it would hardly be possible to obtain a ten-times increase.

Cooling of Slides in Still Projectors

The cooling of slides in a still projector is different from film in a moving projector in that the slide has to remain exposed for a long period and the thermal conditions reach equilibrium. The heat is absorbed from the beam of light at a constant rate whatever the temperature of the slide, but as the slide warms up the efficacy of the cooling increases. After a few minutes the rate of losing heat will become the same as the rate of absorbing it, and the temperature will rise no further. This temperature must not be so high as to damage the slide.

Cooling by Natural Convection of Air. Most simple projectors rely on natural air cooling of the slide, and this method is frequently used successfully for dissipating the heat absorbed by a glass filter, such as Chance ON20 glass. The air adjacent to the glass is heated and rises, thereby causing a natural cooling draught.

In a slide the heat is mainly developed in the dense parts of the picture, but with natural cooling it travels to some extent all over the slide, the whole of it becoming hot. The maximum temperature which gelatin will withstand for 30 min without turning brown is about 180 C and this appears to be the limiting factor, although on some slides the glass will break before the gelatin chars.

With natural convection of air, the rate of cooling is theoretically equal to:

$$0.0004\ T^{1.25}/h^{0.25}\ \text{w/sq cm}$$[9]

where T = temperature of slide above temperature of air (C)
h = height of slide (cm)

This presupposes no obstruction to the air from the slide-holder, and also no cover glass; the total area is twice the area of the slide, because heat will be lost from both sides. If a cover glass is used, the cooling will be less effective because of poor heat transfer from the emulsion to the cover glass. For cut film sandwiched between two glasses, the cooling will be reduced still further.

Particularly in the case of glass heat-absorbing filters, which can run at a higher temperature than a slide, a significant amount of heat will also be lost by radiation:

$$\text{Rate of cooling} = 5.7.\epsilon.(T_1^4 - T_2^4).10^{-12}\ \text{w/sq cm}$$

where ϵ = emissivity = 0.9 for glass
T_1 = temperature of glass (K)
T_2 = temperature of surroundings (K)

It is found by experiment that the maximum safe intensity of heating of a 3¼-in. square slide without a cover glass is 0.25 w/sq cm. A glass heat-absorbing filter will withstand about 1w/sq cm with natural air cooling.

Forced Air Cooling of Slides. Where a greater light output is required it is necessary to use forced cooling of the slide, air cooling being far the most convenient. A similar technique might be used to remove the heat from a glass heat-absorbing filter, or even a color filter used in color stage effects.

In such a system the dense parts of the picture become hot and the clear parts remain fairly cool. Heat is not conducted well from one part of the slide to another, and it is calculated, and confirmed experimentally, that if a large dark area is adjacent to a large clear area, the temperature has fallen to a third at a distance of about 0.5 cm from the dark area. As a result of this uneven heating and consequent differential expansion, large stresses may be set up in the glass, and failure occurs by fracture of the glass, usually along the boundaries between dense and clear areas.

The slides would be less likely to break if they were made on plates of quartz or a heat-resisting glass (not a heat-*absorbing* glass). Such plates are liable to have small bubbles or blemishes and are costly, so that they would probably have to be re-used, either by transfer-sensitizing them before printing, or by transferring on to them the finished print made on cut film. For studio process work it is preferred to use standard lantern plates, combined with an adequate slide-cooler on the projector.

Action of the Air Stream. The action of the stream of air is shown diagrammatically in Fig. 5, blowing across a greatly enlarged view of one side of the slide. The air in contact with the slide is considered to be at rest, being "stuck" to the slide. Immediately above this "layer" is another, which "slides" on the first, and so on, layer after layer sliding on the previous one. Some distance from the slide these layers become no longer laminar and begin to become unsteady, and further still they become turbulent, eddying and swirling. This whole effect occurs within about 1/50 in. from the slide, within the "boundary layer."

Air is a very poor conductor of heat, which is therefore only to a small extent conducted through the first slow-moving "layers." Thereafter the heat is transferred with increasing effectiveness as the turbulence increases until the heated air is mixed thoroughly into the main air stream. The distributions of velocity and temperature, on passing out into the air stream, are sketched in Fig. 5.

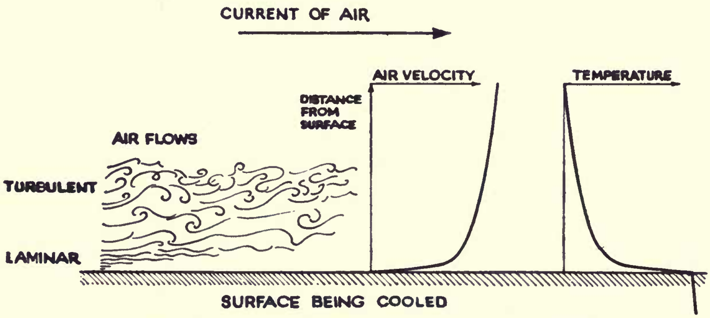


Fig. 5. The action of air in cooling a surface.
Left, air flow changes from slow-moving laminar flow to rapid turbulent flow; center, graph showing greatly reduced velocity near the surface; right, graph showing distribution of temperature on passing from the surface out into the air stream. The thin boundary layer acts as a blanket over the surface.

The chief aim in forced air cooling is to reduce the effect of this slow-moving "blanket" of air over the slide, and this is mainly achieved by using a very high air velocity. Consequently, the temperature of the main stream of air does not rise very much, and a relatively large amount of air has to be used. A great deal of data is available[9] on cooling by air within pipes, which may be of circular or rectangular section. This data may be used if a glass window is placed on each side of the slide to form a tall but thin channel, and the air is blown through this.

The rate of cooling which may be obtained with such a system is equal to:

$$\frac{0.14.V^{0.75}.\rho^{0.75}.C_p{}^{0.75}.K^{0.25}T}{t^{0.25}} \text{ watts per sq cm}$$

where V = air velocity, cm/sec
ρ = density = 0.0012 gm/cm³
C_p = specific heat = 0.24 cal/gm C
K = conductivity = 0.00006 cal/-sec cm² C/cm
T = difference in temp. of slide above air, C.
t = thickness of each air passage, cm

It is calculated that in such a system the emulsion side of the slide is only 10 C hotter than the far side, so that the total area cooled is twice the area of the gate.

The important points revealed by this formula are:

(1) The only quantity which can be varied in practice to any great extent is the velocity. Unfortunately due to the 0.75 power, to increase the cooling requires an even greater increase of air velocity, and in addition there is an upper limit to the velocity. In practice this is not the theoretical one of the speed of sound in air, but arises from the fact that at a certain velocity the slide becomes unstable and begins to vibrate. Even so, the rate of cooling could be perhaps doubled above our present limit; and if the light output of the projector is to be increased further the size of the gate must be increased—to perhaps whole-plate size for half a million lumens.

(2) The value of T is determined by the temperature which the slide will withstand without breaking and also by the air temperature. Compared with using air at room temperature, a slight improvement might be obtained by using precooled air. It is, however, difficult to arrange for the supply of a fair quantity of air at a temperature below 0 C, for the cooling equipment becomes covered in ice and frost. Rather than go to this trouble, it is considered to be far preferable to use uncooled air and increase the velocity a little.

(3) It is some advantage to reduce the thickness of the air passages. They must not be made so small as to require too great a pressure to force the air through the slide-cooler, nor to be seriously affected by the usual variations in thickness of the glass of the slide.

Design of a Slide Cooler. A slide-cooler embodying these principles[10] has been developed for a high-power studio process projector,[11] and is shown diagrammatically in Fig. 6. The air is supplied at a small pressure through a nozzle which contracts in the plan view shown, and gets wider in side view until it covers the height of the slide. Another nozzle connects to an exhaust pipe, and providing it is of small angle as shown recovers much of the velocity pressure head at the slide.

The particular advantages of using the glass windows are (1) to obtain the high air velocity; (2) to make it uniform all over the slide; (3) to obtain silence; and (4) they probably make the boundary layer thinner. By using surface-coated optical glass for the windows the light loss is only 6%. One window is fitted in a door to permit insertion of the slide, which is clamped along its upper and lower edges. Along each side edge there is a thin metal strip to give streamlined air flow at the leading and trailing edges of the slide.

Air Supply System. Consideration was first given to obtaining the air from an impellor pump or compressor, but it was found to be impractical to silence such machines sufficiently to permit their use on the projector, which is used unblimped and unboothed on an ordinary sound-recording stage.

The air is therefore obtained from the studio compressed-air supply and the equipment is shown in Fig. 7. It was found that noise occurs wherever there is a marked drop of pressure. All the air passes at full pressure (70 lb/sq in.) through the air filter, which removes water and dust. The pressure is reduced by an ordinary control valve which is surrounded with a small blimp. The loud hissing sound in the air is removed by a most effective silencer, which is itself blimped. The air, now at only 2 to 6 lb/sq in. pressure, passes to the slide-holder and a gauge indicates the air flow. Flexible pipes are provided to enable the slide to be tilted, lifted and panned. The air becomes slightly more noisy on passing

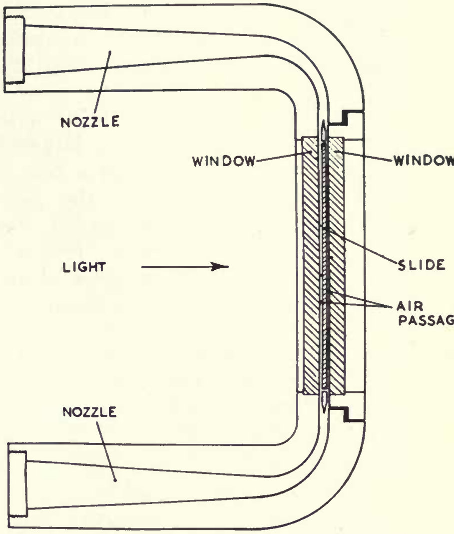


Fig. 6. Diagrammatic cross-sectioned view of slide-cooler.

Glass windows close to each side of the slide form thin channels through which air is blown at a very high velocity.

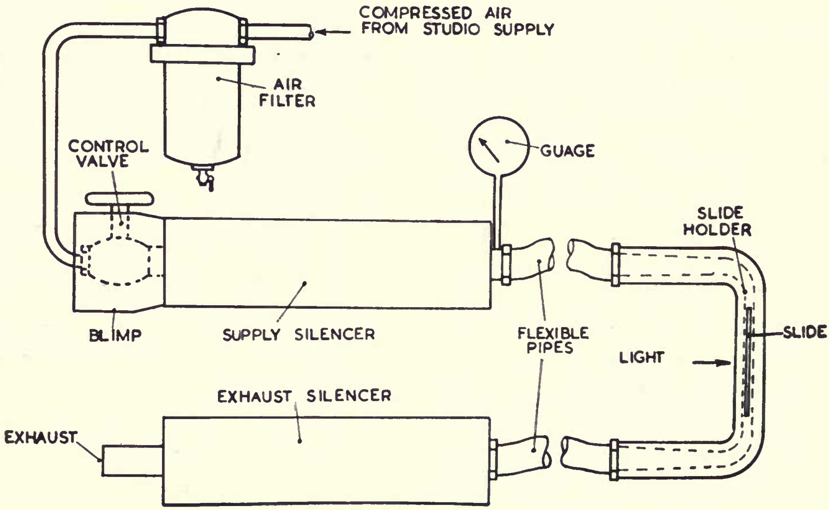


Fig. 7. Schematic diagram of arrangement for supplying air to slide-cooler from studio compressed-air supply.

Pressure is reduced at the control valve, and silencers remove the noise.

the slide at such high speed, but another silencer removes this and the air is practically silent as it exhausts into the room.

Results in Operation. This slide-holder is fitted to a process projector delivering 60,000 lm through a 3-in. × 2.2-in. gate, incorporating the heat-absorbing cell and water-cooled condenser lens described above. It is possible to project ordinary slides of any density for many hours without any damage. The equipment is so silent that it is possible to use it for all shots without troubling the sound recording, and it is not necessary to arrange any sound-reducing flats or blankets between the projector and the microphone.

The quantity of air used is measured to be 50 cu ft/min at atmospheric pressure, giving a calculated air velocity of about 340 mph. The total amount of heat extracted from the slide is 360 w, as measured experimentally.

Acknowledgments. Throughout this work the greatest assistance has been given by Dr. B. V. Bowden, of Sir Robert Watson-Watt and Partners, Ltd., scientific consultants to the J. Arthur Rank Organisation, Ltd. The combined heat-absorbing cell and lens, and the optical system of the high-performance 35-mm process projector mentioned were designed by Mr. A. Warmisham and his staff, and made by Taylor, Taylor and Hobson, Ltd.

References

1. Hugh McG. Ross, "The heating of film and slides in projectors," *J. Brit. Kinemat. Soc.*, vol. 16, pp. 38–54, Feb. 1950.
2. F. J. Kolb, "Air cooling of motion picture film for higher screen illumination," *Jour. SMPE*, vol. 53, pp. 635–664, Dec. 1949.
3. B. S. Cooper and F. S. Hawkins, "Spectral characteristics of light sources for facing and degradation tests," *J. Soc. Dyers and Colourists*, vol. 65, pp. 586–596, Dec. 1949; see also: F. T. Bowditch and A. C. Downes, "Spectral distributions and color temperatures of the radiant energy from carbon arcs," *Jour. SMPE*, vol. 30, pp. 400–409, Apr. 1938; R. G. Linderman, C. W. Handley and A. Rodgers, "Illumination in motion picture production," *Jour. SMPE*, vol. 40, pp. 333–367, June 1943; W. Finkelnburg, "The high current carbon arc," *FIAT Final Report* 1052, PB-81644, Office Technical Services, U.S. Dept. of Commerce, Washington, D.C., 1949; C. E. Greider and A. C. Downes, "The carbon arc as a source of artificial sunshine, ultraviolet and other radiation," *Trans. Illum. Eng. Soc.*, (Amer.), vol. 27, pp. 637–653, Sept. 1932.
4. Th. Dreisch, "Die Absorptionkoeffizienten einiger flüssigkeiten und ihrer dämpfer im ultraroten unterhalb 3μ," *Zeit. für. Physik*, vol. 30, pp. 200–216, 1924; and *International Critical Tables*,. vol 5, p. 269, McGraw-Hill, New York.
5. Data Sheets Nos. 5.1315 and 5.131, and *Catalogue of Coloured Optical Glasses*, Chance Bros., Ltd., Smethwick, England.
6. Designed by Taylor, Taylor and Hobson, Ltd., England. Patents Pending.
7. R. J. Zavesky, M. R. Null and W. W. Lozier, "Study of radiant energy at motion picture film aperture," *Jour. SMPE*, vol. 45, pp. 102–108, Aug. 1945.
8. E. K. Carver, R. H. Talbot and H. A. Loomis, "Effect of high-intensity arcs on 35-mm film projection," *Jour. SMPE*, vol. 41, pp. 69–87, July 1943.
9. The theories of cooling in this paper are based on *Heat Transmission*, W. H. McAdams, McGraw-Hill, New York, 1942.
10. Patents Pending.
11. Hugh McG. Ross, "A new still process projector," *J. Brit. Kinemat. Soc.*, vol. 17, pp. 159–170, Nov. 1950.

A 35-Mm Process Camera

By John P. Kiel

This paper describes the unique features of the Acme Process Camera and their applications to special effects photography. Basic camera-design features include a color wheel for three-color successive-frame photography, interchangeable film movements with various locations of the register pins, a reflex viewer, embodying register pins in optical alignment with those of the film movement, projection facilities for "matte painting" which allow processed stock to be located on the register pins of the viewer and the image projected through the photographic objective. The electrical and mechanical operation of two new types of drive motors, the Acme stop-motion motor and the variable-speed synchronous motor, and their use in conjunction with the camera are also discussed.

Commercially-built process cameras are not commonly used in studios at the present time. Without intending to expand procedures, studio technicians often alter an obsolete production camera to enable it to perform an individual phase of special effects photography. This usually proves quite adequate for one particular procedure; however, the process department is often hampered by the limitations of its equipment.

The Acme Process Camera does not represent a radical change in design or mechanical operation, but presents a combination of technical benefits which have resulted in a more versatile camera which will, in turn, increase the range of activity of the process department.

Presented on April 28, 1950, at the Society's Convention at Chicago, Ill., by John P. Kiel, Producers Service Co., 2704 W. Olive Ave., Burbank, Calif.

The various general attributes of the camera will be considered individually. Their relation to practice is somewhat dependent upon the imagination and ingenuity of the process department; however, the conventional procedures will be annotated.

A feature which will readily be appreciated by the cinematographer is the accessibility of the operating mechanism from the side of the camera (Fig. 1).

Intermittent Film Movement

The highest degree of accurate and positive film registration is essential for color separation negatives, matte shots, and other photographic procedures employed by the process department; therefore, the film movement is of the solid, or stationary, register-pin design (Fig. 2). This particular method of film registration is extremely accurate because there is no mechanical action

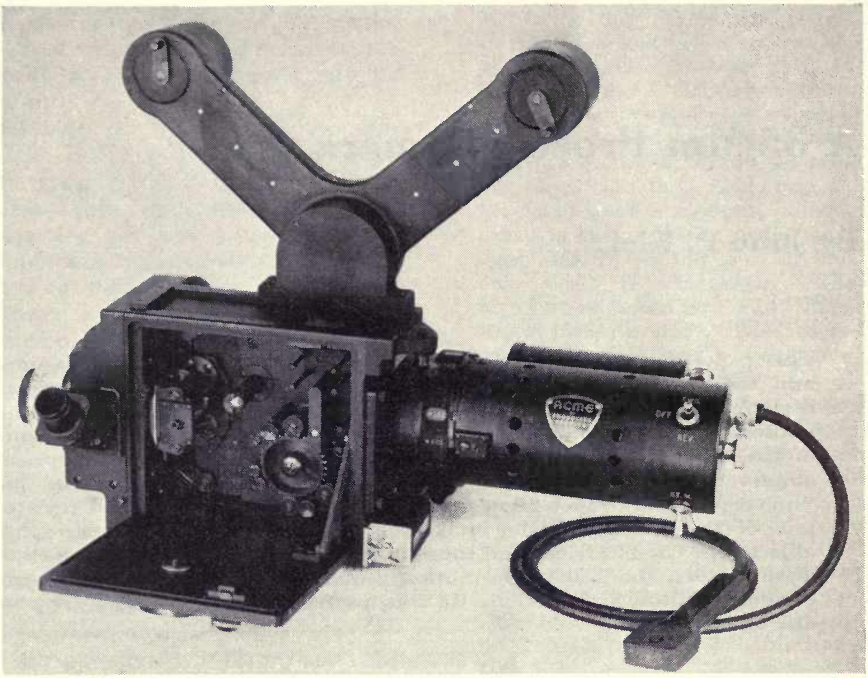


Fig. 1. Internal mechanism, stop-motion motor, and automatic take-up device.

or motion of the register pins. They are mounted directly to the movement base plate.

The register pins are in horizontal alignment. One register pin is "full-fitting" in the film perforation; the other is "full-fitting" vertically and undersize horizontally, thus compensating for shrinkage of the film without sacrificing accuracy of registration. So accurate are the movements that a single strip of film may be exposed a multitude of times and yet maintain perfect registration. This exact duplication of registration is assured regardless of the direction of film travel.

To eliminate the possibility of film damage, no pressure is applied to the film during the pull-down cycle. After the film is located on the register pins, and just before the shutter opens, a

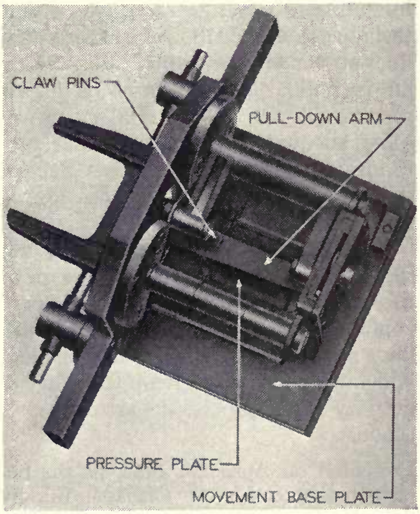


Fig. 2. Intermittent film movement.

small amount of pressure is applied. However, the accuracy of film registration is not dependent upon this pressure. It serves only to hold the film in the focal plane during the exposure.

Engagement of the film perforations on the register pins prior to the exposure and disengagement during the pull-down cycle are performed by the pressure and stripper plates. These plates are made of stainless steel and all surfaces which contact the film are hard-chrome plated for extra protection against scratching.

An especially advantageous feature of the film movement is its ability to accommodate 1, 2 or 3 strips of film and yet maintain perfect registration on all of the strips.

The spring-loaded pressure plate automatically compensates for, and applies equal pressure to, the various numbers of films. This system eliminates manual adjustments of the camera cam when alternating single strip, bipack and tripack methods.

To enable the use of this camera in conjunction with existing studio equipment and procedures, the film movements are supplied with the register pins either above or below the aperture and with the large, or "full-fitting," pin located at any one of the corners of the aperture.

The film movements are easily removed and completely interchangeable within the accuracy of 0.0001 in.; consequently, supplementary movements with the various register-pin locations can be used. This selectivity and interchangeability not only provide film movements which coincide with the optical printer and/or production camera, but will also facilitate and augment the bipack methods presently employed for special-effects and two-color photography.

Printing two-color bipack negatives to the separation positives, and process shots from these positives, best exemplifies the feasibility of supplementary movements. Because of film shrinkage and inaccuracies of the perforations, it is essential, for good quality image, to register consistently with the same "full-fitting" perforation as well as the same pair of perforations as are used for the original negative.

As is well known to users of bipack photographic methods, when the two films are simultaneously exposed in the emulsion-to-emulsion superimposed manner, the "full-fitting" register pin locations of the two records are opposite from right to left in relation to the emulsion and image. Orienting the registration perforations of the bipack negatives for contact printing the separation positives and subsequent process shots, therefore, requires a supplementary movement which will conform to the "full-fitting" perforations of the panchromatic record, when its emulsion-to-light source relationship is necessarily reversed from that of the original exposure. The orthochromatic record, which is exposed through the film base, and therefore retains the same emulsion-to-light source relationship, requires registration locations identical to, i.e., the same movement as, that used for the original exposure.

Step-printing the bipack negatives to duplitized positive stock is equivalent to printing separation positives and also requires two film movements with reverse registration locations.

Figure 3 illustrates the locations of the register pins and the left-to-right image relation of three-color, three-strip negatives. Again, as in two-color, the locations of the "full-fitting" perforations are reversed due to the emulsion-to-emulsion operation of the red and blue records. At the lower part of the figure, the three records are viewed from the emulsion side and it may be seen that the registration perforations of the blue and green records correspond, and the red record is dissimilar.

To prevent deterioration of image quality, the three-strip positives are printed in the emulsion-to-emulsion

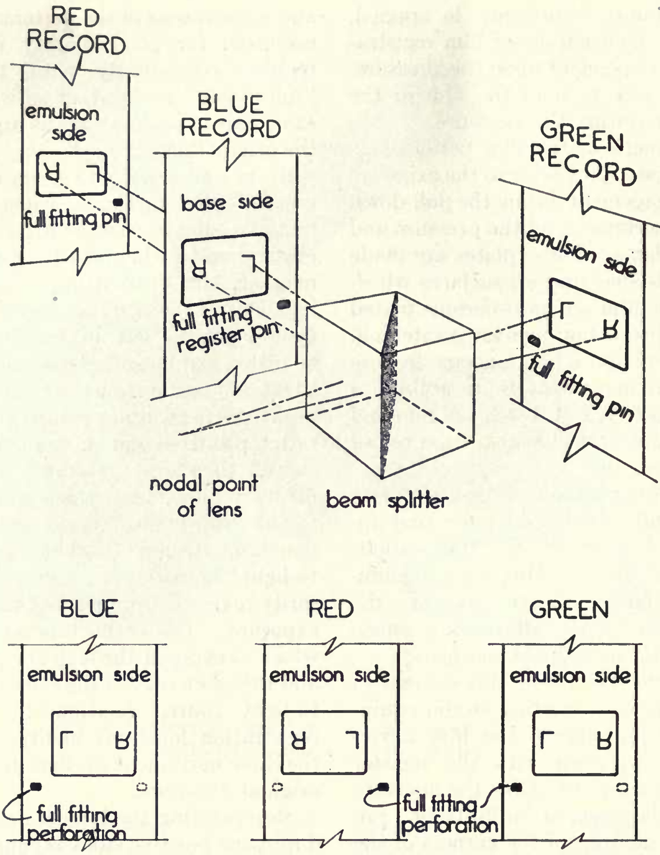


Fig. 3. Typical three-color, three-strip registration locations.

manner. Bipack printing and corresponding special effects with these positives, therefore, require two film movements with opposite locations of the large or "full-fitting" register pins.

Viewer

The viewing device is of the positive reflex type which enables the operator to view the image produced by the photographic objective without the necessity of shifting or "racking over" the camera.

A lever is located on the face of the camera which, when actuated, positions a 45°-angle, first-surface mirror between the photographic objective and the photographic aperture. The image which would normally be produced on the film is then diverted to a ground glass and corresponding aperture in the viewer. This image of the objective scene, as observed through the viewing tube, is magnified approximately two times and is erect and correct from left to right.

A safety device prevents the camera-drive motor from operating while the viewer is employed.

Also embodied within the viewer are

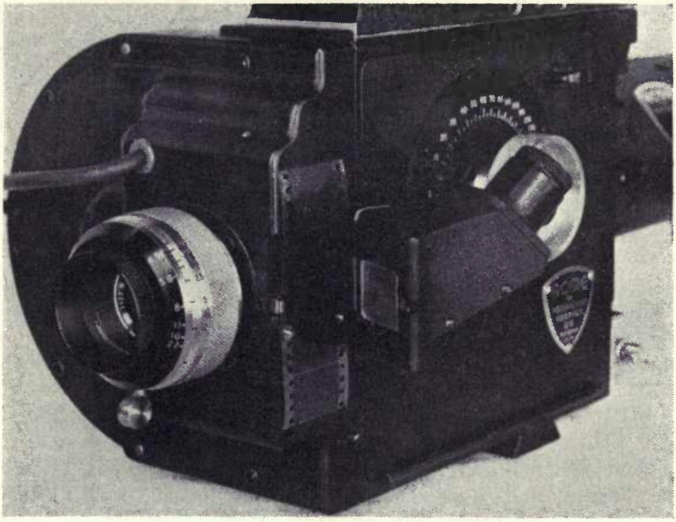


Fig. 4. Three-quarter front view of camera showing processed stock located on the register pins of the viewer for obtaining a composite or matte-shot view.

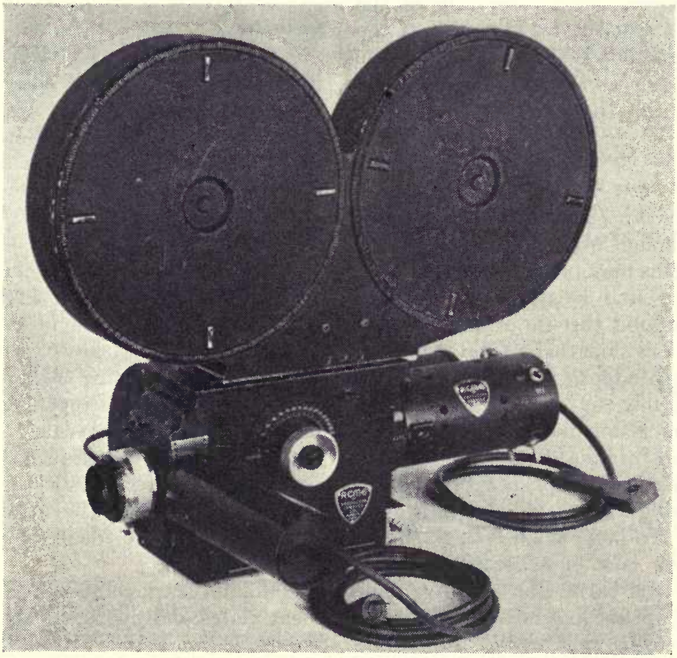


Fig. 5. Side view of camera with lamphouse attached.

two register pins which are in exact optical alignment with the register pins of the movement. By placing a piece of processed stock on the register pins of the viewer (Fig. 4), a matte-shot view or a compositive view of the objective scene is obtained, thus assuring exact composite alignment and registration during future printing operations.

The viewing tube may be removed and a lamphouse substituted for it (Fig. 5). This arrangement allows processed stock to be located on the register pins of the viewer and its image projected through the photographic objective. From this projected image, a matte may then be painted. This method of matte-shot projection does not expose the raw stock threaded in the camera. When the viewer release button is pressed, the reflex mirror retracts and allows the painted matte to be photographed.

Because of the exact optical alignment between the register pins of the movement and the register pins of the viewer, composite alignment of the original scene and of the matte shot is assured during the bipack printing operation.

Lens and Lens Mount

The lens is a 75-Mm Ektar Enlarging Lens, although other lenses varying in focal lengths may be utilized.

The size and location of the reflex viewer prohibit the use of lenses of the "shorter focal lengths." The minimum focal length adaptable to the camera is approximately 62 mm, although this varies and is dependent upon the particular lens formula.

Focusing is accomplished by rotating the focusing ring in the conventional manner. To prevent an "image shift," due to the lack of a common optical axis, the lens barrel and elements slide along the optical axis but do not rotate.

The focusing ring index is graduated for both single-strip and bipack focusing. The bipack index compensates for the variation of the focal plane when photographing through the film base.

Color Wheel

Built in between the aperture and the lens is a color wheel that contains the necessary neutral density and color filters for three-color, successive-frame photography.

This color wheel rotates synchronously with the camera shutter and places, in sequence, the blue, red and green filters in front of the film during the three successive-frame exposures.

To convert the camera to black-and-white photography, a lever on the front of the camera case is turned. This retracts the color wheel from its position in front of the film, but does not affect the synchronism between the shutter and the color wheel. Shifting the control lever is the only manipulation required to reconvert the camera to successive-frame color photography.

Counter

A foot and frame counter is provided; its accurate, reversible characteristics facilitate duplication of frames for multiple-exposure shots. Both footage and frames are recorded on one resettable unit.

Adjustable Shutter

The range of shutter opening is adjustable from 0°, or completely closed, to a maximum opening of 170°. The large knob on the side of the camera regulates this opening and it is indicated in degrees of opening by the pointer and graduated scale.

An optional automatic shutter device produces the selective fades of 1-, 2-, 3-, 4- and 8-ft lengths. This attachment is located at the back side of the camera as shown in Fig. 6.

A unique gearing and linkage arrangement closes and opens the shutter at a semilogarithmic differential. That is, when closing, the amount of shutter variation between successive frames

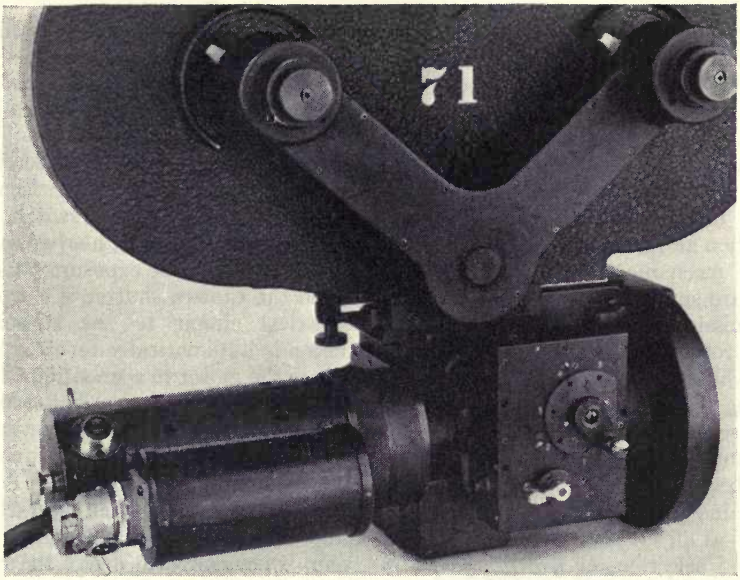


Fig. 6. Back side of camera embodying automatic shutter attachment.

gradually decreases as the shutter approaches the closed position. When opening, the variation operates inversely.

Because this fade operation is based on variations of the percentages of exposure, it will more accurately produce "smooth" lap dissolves wherein the combined densities of the exposures will approach matched densities throughout the dissolve action.

Magazine Drive

Automatic film take-up, both forward and reverse, is accomplished with the magazine drive unit (Fig. 1). This completely gear-driven device eliminates belts, pulleys and manual operations when changing the direction of the film travel.

Located at each magazine spindle is an overriding friction clutch. Its multiple-friction-disk design assures uniform film tension throughout the film roll.

Magazine drives are available for use with either 400-ft or 1000-ft capacity magazines.

For bipack magazines the conventional pulley-and-belt type take-up may be obtained. It is mounted on the camera case in the same manner as the automatic magazine drive and is interchangeable with it.

Buckle-Trip

In the event of take-up failure, a buckle switch automatically stops the camera-drive motor. The buckle-trip arm is dual and is located above the sprocket at both the take-up and take-off side of the film magazine, thereby protecting against take-up failure when the camera is operating in either forward or reverse.

Removal of the film buckle, by manually rotating the magazine spindle, automatically resets the buckle switch and eliminates the necessity of opening the camera door.

Motor-Drive Units

Two types of motor-drive units are available for use with the camera. They are:

1. The stop-motion motor (Fig. 1), for single-frame exposure; and
2. The variable-speed, synchronous drive motor, featuring synchronous operation at various speeds.

The mechanical operations of these units are similar. In both units a gear transmission is located between the motor rotor and the camera-drive shaft. The various speeds are obtained by shifting the gears of this transmission. Because the speed of the motor proper is constant and friction slippage devices have been eliminated, exact speeds are maintained with full motor power delivered at all speeds.

Speed selection, or shifting gears, is accomplished by turning the knurled dial, located at the front of the motor housing, to the desired speed.

The variable-speed, synchronous drive motor delivers the synchronous speeds of 24, 16, 12, 6, 3 or 1.5 frames per second.

The stop-motion motor combines stop-motion action with selective speeds or exposure times. These exposure times are ¼, ½, 1, 2 or 4 seconds in duration; however, an infinite exposure range is possible by regulating the angular opening of the dissolve shutter.

For rewind and title work, a $\frac{1}{16}$-second exposure is provided which operates continuously only; all other speeds operate either continuously or with stop-motion action.

The stop-motion is actuated by a remote, portable pushbutton switch. Each time the switch is pressed the camera makes one exposure.

For three-color, successive-frame, animation photography, a selector switch is provided which changes the ratio to three exposures each time the switch is pressed.

The automatic stopping action of this unit is controlled electrically with microswitches and a centrifugal switch. After the stop-motion unit has driven the camera through the exposure cycle, and while the camera shutter is closed, the electrical circuit to the stop-motion motor is automatically reversed. This brings the motor to a smooth, but quick stop. Prior to its normal action of starting in the opposite direction, the centrifugal switch opens the circuit and the motor remains stopped. Pressing the push-button switch restarts the stop-motion motor in its original direction, which, in turn, drives the camera through the ensuing exposure cycle.

Both the stop-motion motor and variable-speed, synchronous motor operate either forward or reverse. This reversing switch and the other necessary electrical receptacles are embodied in the end-bells of the motor.

A threading knob at the rear of the motor units enables the operator to rotate the motor manually for film loading.

The drive units may be interchanged quickly by removing four screws at the rear of the camera case.

Due to the increasing demand for precision 16-mm process equipment, a 16-mm model process camera has also been constructed. Its design is practically identical to the design of the 35-mm model. Because of the different requirements of 16-mm photography, the color wheel of the 35-mm model is omitted on the 16-mm camera.

Revision of PH22.15 and PH22.16

Formerly Z22.15 and Z22.16

MINOR REVISIONS of two American Standards, Z22.15—1946 and Z22.16—1947 ("Emulsion and Sound Record Positions in Camera for 16-Mm Sound Motion Picture Film" and "Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Mm Sound Motion Picture Film"), have been proposed by the Standards Committee. The proposed revisions of the existing Standards appear on the following pages.

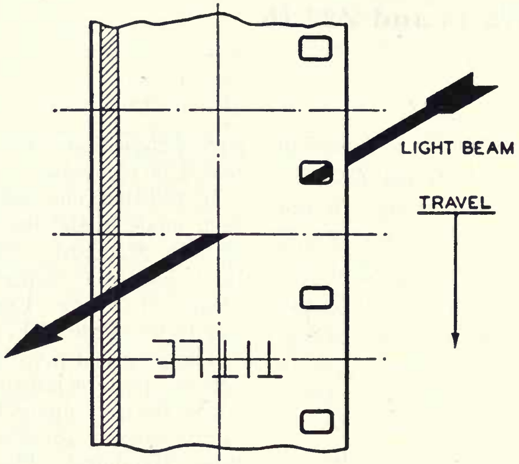
Since the designation of the guided edge is not an essential nor a proper part of these Standards, it was proposed that it be eliminated.

In addition, one editorial change has been made in the title of paragraph 2 of each Standard. "Speed of Projection" has been changed in Z22.15 to "Rate of Frame Exposure" and in Z22.16 to "Rate of Frame Projection."

The proposed revisions are published here to invite comments and criticism, within the next ninety days, by members of the Society or others interested in these Standards. Please forward any comments to Henry Kogel, Staff Engineer, at Society Headquarters, by September 1, 1951.

Proposed American Standard **Emulsion and Sound Record Positions in Camera For 16-Millimeter Sound Motion Picture Film**	**PH22.15** Revision of Z22.15-1946*

*UDC 778.53



Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Rate of Frame Exposure

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 26 frames.

*Elimination of "Guided Edge" is the only revision from the 1946 edition.

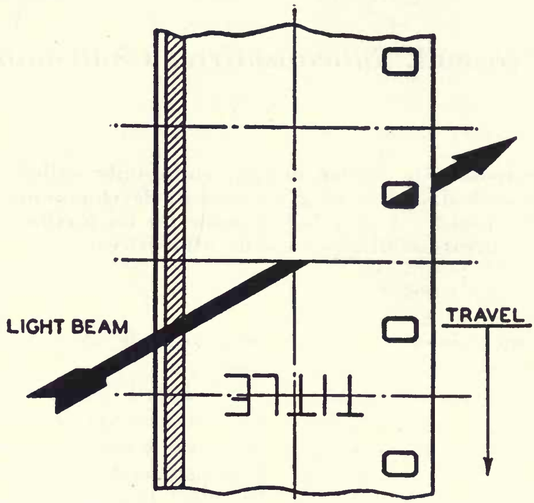
NOT APPROVED

Proposed American Standard

Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16-Millimeter Sound Motion Picture Film

PH22.16

Revision of Z22.16-1947*



Drawing shows film as seen from the light-source in the projector.

1. Emulsion Position

1.1 The emulsion position in the projector shall be toward the lens, except for special processes.

2. Rate of Frame Projection

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 26 frames.

*Elimination of "Guided Edge" is the only revision from the 1947 edition.

NOT APPROVED

New All-Purpose Film Leader

A Status Report, April 1, 1951, of the Subcommittee on Film Leaders of the Films for Television Committee

By C. L. Townsend, *Subcommittee Chairman*

A new all-purpose film leader design, commonly called "The Society Leader," is described, its history given and its development, tests and uses to date are discussed. A proposal is made for its further application to motion picture prints of all types and for all services.

1. *Preliminary Conclusions*

In the one and one-half years of its existence the Subcommittee on Film Leaders has worked to produce a new leader design retaining all the excellent features of the Academy Leader now in general use, and providing some features which are highly desirable from the viewpoint of a new and growing user of film productions—television. It is believed that this has been accomplished.

Early in the work a purely television-centered program was abandoned in favor of a broadly applicable design. Since then the leader has been tested by commercial laboratories, professional theater projectionist groups and equipment manufacturers. Careful attention was given to the proposals of each and a gratifying spirit of cooperation and understanding was developed.

The New York offices of several television companies have been using the new leader on their television recording releases and on certain other television films. More than 10,000 prints have been so made and used with excellent results.

It is hoped that all interested persons will consider the proposed leader carefully, use it widely for test and evaluation, and send the Subcommittee their findings. It is the intention that a proposal for standardization shall be made when widespread results warrant it.

2. *Features of the New Leader*

The present American Standard Z22.55–1947 is the foundation for the new leader design. Only additions have been made, and only such additions as cause no deletion of past features. Under Z22.55, paragraphs (1) and (2) remain unchanged. Paragraph (3) is changed only as to frame content, and paragraphs (4), (5), (6) and (7) are unchanged.

2.1: The main body of the leader ahead of the three-foot mark is changed from a solid black to an appropriate simple pattern (see illustration). The design is intended to be used in television to permit checking system operation before switching into the first picture frame.

Submitted for publication April 27, 1951.

The basis of the pattern is familiar to most television engineers. A neutral gray background provides a foundation for the pattern proper, which consists of two concentric circles having diameters in the ratio of 4:3, and four arrows whose tips establish the limits of scanning as defined by the SMPTE Television Test Reel.

Approximately equal areas of black and white are used to provide reference levels for video gains and pedestal settings. These two limits, together with the background gray, provide a rough check of system transfer characteristic, since the gray value used is approximately centered between the black and white tones. Experience will indicate where the gray level should fall on the wave-form monitor when the system provides best reproduction. The assigned density values of these areas are:

White	0.2 ± 0.1
Gray	1.0 approximately
Black	2.0 ± 0.2

The pattern also provides a secondary indication of scanning adjustment and camera-projector alignment. This will greatly reduce the need for "blind" switching; that is, for switching into a film sequence from equipment having only accidental scanning control settings.

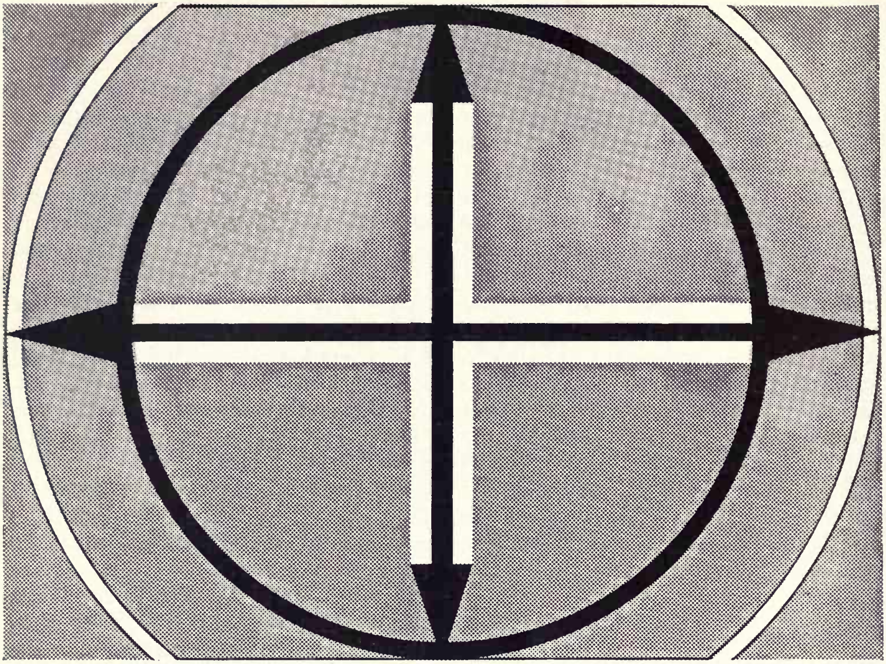
Much of the above information can be gained during the rolling time of a normally threaded leader. In addition, when stop-frame projection is available (its use is rapidly increasing), the projected pattern permits advance check of the entire electrical system, including effects of beam current, edge-light, back-light, etc. Also, the presence of the "average video" information between cue numbers reduces the tendency of the system to "bounce" as the cues go by.

2.2: The footage numerals have been changed to project right side up. It has been found that precise television program switching has caused these numerals to become of great value to program directors. They can count to their first-frame cue from the rhythm set by the passing numerals, resulting in excellent switching accuracy. Right-side-up projection makes them easier to read for this service. To prevent errors of reading by both production directors and projectionists the "SIX" and "NINE" markers are spelled out.

2.3: The picture threading frame for each 35-mm foot is identical with the old leader, consisting of a full white background with black numerals overlaid. No threading problems are introduced there. However, a single frame, when projected, does not have enough visual effect to permit positive recognition of the numeral; therefore, each numeral is repeated one frame before and one frame after each threading frame, but with the outer portions of the main target design added. As seen in the illustration, there is no possibility of confusing the threading frame with those added for visual effect. This permits normal threading procedures used in theater projection to continue without modification.

2.4: The 35-mm sound threading marks have been changed to read in plain English "35 Sound," replacing the previously used diamond mark. No explanation of function is necessary, therefore, for persons unfamiliar with the use of a leader, as was the case before this change. The lettering used is right-side up to the projectionist, and on the side of the film occupied by the sound track. No change in threading procedure is required.

2.5: 16-Mm sound threading marks have been added to define the sound scanning position for that service. As in the 35-mm case, the sound mark reads in plain English and occurs on the side of the film next to the sound track. The leader can thus be used for both reduction printing and contact work without change.



Main Body Pattern.

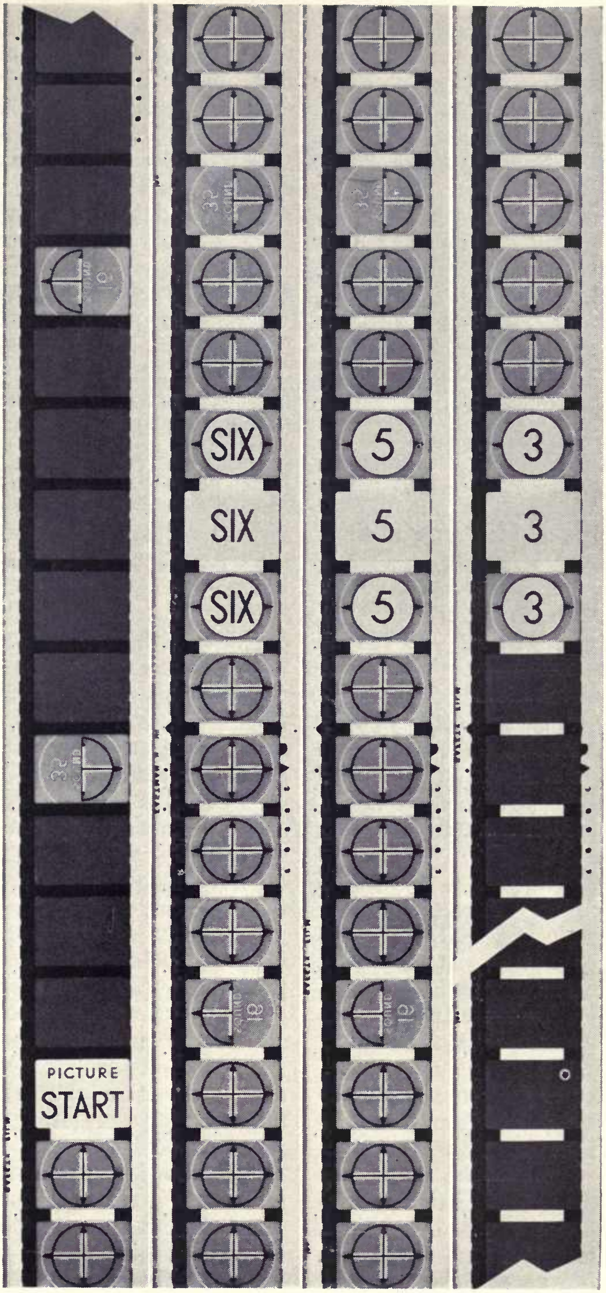
Previously no indication was provided of proper threading for 16-mm use. Yet it has been found that most projectors can be misthreaded. Past practice, in cases of controversy, has been to count 26 frames and mark the sound position with grease pencil. No problems of this sort need occur with the new leader. Of course, the presence of an indication of correct threading position also increases the precision of ordinary operation.

2.6: The black frames following the three-foot marker are slightly changed to a dark gray. The tone value is not altered enough to affect theater projection, but will permit television operations to switch into the dark frames without as much "flare" and "black-spot" as now occur. No change in theater practice is required.

The density value used for these frames is approximately 1.6 but may vary somewhat, depending upon printing conditions. In general, the intention is to provide some iconoscope plate illumination to stabilize its operation.

2.7: A small switching cue (see illustration, third frame above lower right-hand corner) has been added in the eighth dark frame before the first frame of picture. The cue is the standard mark used for change-overs but confined to one frame. It is to be used as an indication to television directors that the picture will start within normal switching reaction time. Since the cue is very small, occurs only on one frame, and is on a part of the film not normally shown in theaters, it will not affect theater practice in any way.

The switching cue also gives a clear indication to a cutter when a particular leader has been used too often, resulting in excessive loss of frames due to splicing. A few frames can be lost without serious consequences, but when their



Sample Footage From Proposed Leader.

Read from the upper left to the lower right; broken edges indicate duplicate frames deleted.

number exceeds four or five, that leader should not be re-used.

2.8: Reel identification standards have not been changed. It is worth noting, however, that nonstandard practices have grown up, particularly in television film-making. American Standard Z22.55–1947 defines proper procedures and should be followed rigorously. The proposed leader is carefully designed to supply needed information throughout its active length. It should not be mutilated by slates or special markings in any position other than the standard allows or its usefulness will be greatly impaired.

3. Evaluation

3.1: Any new thing is strange at first, inevitably. Every effort has been made to reduce this strangeness by retaining unimpaired the previous functions of the leader. But each new function has introduced some new appearance. It is suggested that evaluation be a slow process, with time for all to become familiar with the entire content of the leader. In this way the information in it which is not pertinent to the particular use can be ignored and full attention can be given to the useful cues.

For instance, suppose a production director is primarily interested in the footage cues. He may at first see the sound cues too clearly, but once they have become familiar, and he knows they are of no importance to him, they will recede in visual impact and become completely unnoticed.

Again, a theater projectionist may be primarily interested in the threading cues and feel that the television pattern is confusing; but once he thoroughly understands the pattern, it is of no interest and so diminishes in importance, permitting the useful cues to emerge. Whenever a little time has been allowed for this phenomenon to take place, no permanent objections have been registered.

3.2: Some feeling has been expressed that the leader is "hard to print." As compared with the dupe of a dupe of a dupe sometimes used for the old leader, it is somewhat more difficult. But any good laboratory can do a thoroughly acceptable job without difficulty, and the result is good dressing for a fine printing job.

4. History and Development

In January of 1950, F. T. Bowditch, the Society's Engineering Vice-President, decided that the information which had been submitted to him on present leader deficiencies warranted an investigation. The project was assigned to Dr. R. L. Garman's Subcommittee of the Engineering Committee on Television, and it in turn assigned it to a Subcommittee under C. L. Townsend. When the engineering activities of the Society in television fields were reorganized and expanded a few months later, the project was transferred to the new Committee on Films for Television, with the Leader Subcommittee reporting to that group. It held its first meeting on February 17, 1950.

At first there was some feeling that a special television leader might be produced which would exist as a special-service standard and leave unmodified the old Academy Leader. At that time major design changes were considered, including 24-frame spacing for the threading cues. However, after long debate by representatives of laboratories and projectionists, it was decided that the problems of dual-purpose release (including reduction printing) and the confusion always resulting from dual standards could be avoided by a proper common-use leader design. Thereafter all the efforts of the Subcommittee were directed toward the production of a leader to fit this policy.

From the beginning excellent cooperation was obtained from producers, laboratories, projectionists and broadcasters, resulting in the issuance on April

19, 1950, of the first sample leader (in card form) for limited comment and criticism. Some two months later these comments were embodied in the first sample leader film intended for actual test use. It was then discovered that the projected visual impact of the footage cues was insufficient to permit good cuing, so the two additional cue frames were added, and that version of the leader was tested with good results.

The September 8 meeting of the Subcommittee requested authority for more widespread testing of the leader. Having received that permission, samples were sent to many organizations not represented on the Subcommittee itself. Again the reactions were reasonably approving, except that the Motion Picture Research Council objected on the grounds that the leader would work an undue hardship on theater projectionists.

In order to obtain the reactions of professional theater projectionists to the proposed leader, the services of the Projectionists' Union were enlisted. After several weeks of consideration an enthusiastic report was received from Steve D'Inzillo, the Union's Business Representative.

Other meetings considered and adopted or rejected proposals received until on March 22, 1951, the Subcommittee decided that the foundations for the new leader had been well established, that the time had come to request that it be publicized to the fullest, with the broadest sort of operational and functional test, directed toward the writing of an official standard. This Status Report is intended to be the first step in that direction.

5. The Next Steps

When and if the parent Committee decides that the above extensive test may be undertaken, the Subcommittee will canvass by letter the television film producers and advertising agencies, requesting that the new leader be used on their special releases. It is hoped, also, that the major feature film producers will cooperate in the test. Certainly in this way all possibilities can be explored and all answers firmly given.

The Subcommittee

Charles L. Townsend, *Chairman*
V. D. Armstrong
R. O. Bigwood
L. W. Davee
T. P. Dewhirst
L. B. Gumbinner
C. F. Horstman
H. R. Lipman
K. E. MacIlvain
K. E. Mullenger
J. G. Stott
C. A. Younger

Note: At a meeting held on May 2, 1951, the parent Committee voted permission for the Subcommittee to conduct the test mentioned above.

Progress Committee Report

PROGRESS in the motion picture studios during 1950 was highlighted by the advances in various color systems and the apparent acceptance of color for pictures of all classes and types. The taking speed of the Technicolor system has been increased considerably. Several laboratories within the studios, or serving the studios, have been remodeled to handle the various other color systems which are now in active use.

The drive for production economies continues and a number of different things have been tried with varying success. During 1950 radio communication facilities were used extensively between studios and location units, as well as for the control of production personnel and equipment. The FCC allocated radio channels to the motion picture industry specifically for this purpose. Closer pre-picture planning among the production groups resulting in the reduction of shooting-days per picture has probably been the greatest money-saving factor.

In picture and sound reproduction the work of the Screen Brightness Committee has created a great deal of interest among studio personnel and the results of the 100-theater survey promise to bring about a better relationship between negative density, print density and average projection light.

The various television broadcasters are continuing with the policy of moving into studios where space limitation is not such a serious factor.

Submitted, April 13, 1951.

The use of motion films in television has grown steadily throughout the year. Already a considerable number of shows are being filmed and there are indications that the majority of the sponsored shows may eventually be broadcast from film. Much of this shooting is being done by independent producers, but with increased studio space some television companies are preparing to film their own productions.

The Zenith Phonevision system has been undergoing a consumer test with the permission of the Federal Communications Commission. These tests have used 35-mm films produced for theatrical release. The prints have been regular color releases, or regular black-and-white releases, as well as special black-and-white prints made to Zenith's specifications of density and contrast.

35-Mm Photography

By July of 1950 conversion to safety film was approximately 85% complete. It was stated that Eastman had discontinued the manufacture of 35-mm nitrate positive film for motion pictures Some Eastman safety stock is being used by Du Pont pending production of a suitable safety stock by that company.[1]

The studios are showing more and more interest in traveling matte techniques and considerable work has been done with them, particularly on color.[2]

Color Processes. The Eastman 35-mm negative-positive color process which was introduced experimentally in 1949

has now been used in a number of full-length pictures.[3]

One studio is shooting pictures with Eastman color negative, viewing dailies on Eastman color positive, and will release on SUPERcineCOLOR three-color print stock.[4]

A second studio has made a feature picture on Eastman color negative and will release on Du Pont color print stock.[5,6]

Another studio is shooting a feature picture on Ansco negative-positive and is doing all of the processing in the studio.

Other studios are preparing to produce some of their own color films by any one or more of the afore-mentioned processes, or by shooting on black-and-white stripping film and using the three-color separations for printing on any one of the print stocks.[7]

In France the Gevacolor process is now reported available for release prints. Three full-length features in Gevacolor were produced in France during 1950.

In laboratories in the color field, the Cinecolor Corporation reports the following:

(1) Installation of equipment and production processing of the Eastman color negative film.

(2) Installation of equipment and production processing of the Eastman color positive film (with sound).

(3) Full scale conversion for the SUPERcineCOLOR three-color release printing.[4]

(4) Establishment of the Cinecolor two-color process in Great Britain.

Consolidated Film Industries has equipped both its Fort Lee and Hollywood laboratories for production of "Trucolor." The company is now in release production of the new three-color Trucolor prints. The print stock is Du Pont three-color material type 875 and the original negative is the Eastman Kodak automatic masking three-color film type 5247.

The sequential operations are: three separation prints on panchromatic film from the color negative, three duplicate negatives optical effects incorporated, on gray base stock through selective filters from these prints which are then printed through proper filters for layer selectivity, on the multiple layer Du Pont print stock.[6]

It has been announced that the Du-Art Laboratories in New York will make "Tri-Art" color on Eastman, Ansco and Du Pont color materials.

Technicolor has announced and is at present working with films for the three-strip cameras which are balanced for a color temperature of approximately 3350 K. It is claimed that this system will bring illumination requirements within the range of that now used for black-and-white photography. It was announced that the system will be available for general use within a few months.[8,9,10]

Lighting Equipment and Techniques. Technicolor announced a change in color balance of the three-strip system from that of sunlight to a color temperature of approximately 3350 K. This resulted in the production of gelatin-type filters for the carbon-arc lamps to reduce their color temperature sufficiently for them to operate in conjunction with unfiltered tungsten lamps.

This change is at present in the transition stage. Some time ago the Technicolor system was increased in speed by a ratio between 450 ft-c and 300 ft-c key-light on a white light, or sunlight, basis. Later, by going to a 3350 K basis a further increase in speed to 150 ft-c was announced. This latter increase in speed is, however, applicable only to incandescent tungsten lamps because it is necessary to filter the high-intensity carbon arcs by approximately the amount gained in order to provide a color balance.

At the time of completion of this report only tests and picture sequences

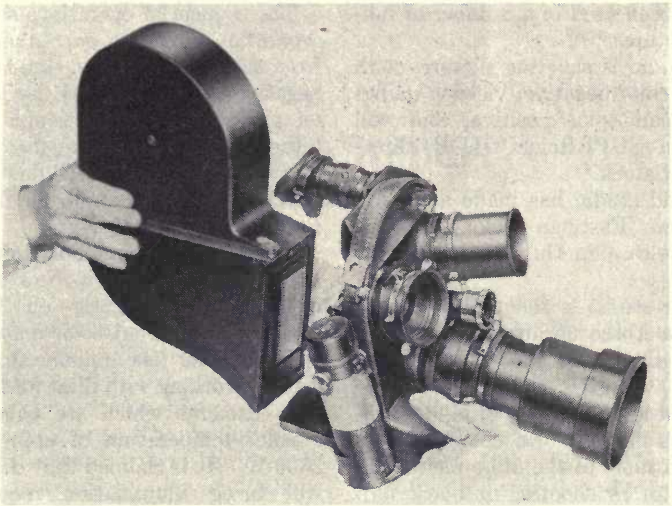


Fig. 1. Eclair "Cameflex" takes 35-mm and 16-mm film interchangeably by changing film magazines.

have been completed with the 150-ft-c system balanced for 3350 K. Productions have been made with the 300-ft-c white light system.[8–11]

In France the Bréguet Company has brought out a new 150-amp automatic carbon-arc lamp for stage lighting which has received considerable notice because of its stability.

While no mercury-cadmium lamps are in present use for set lighting in the West Coast studios, the bulbs are available and are being evaluated by the Research Council.[2]

Reflector-type incandescent bulbs such as photoflood and photospot lamps have been increasingly used on location where the documentary type of lighting is indicated and for non-theatrical releases.[2,12,13,14]

Cameras and Accessories. A system for special effect shots has been devised and applied at present to panning and tilting the camera, which permits the cameraman to pan and tilt the camera in a normal manner and follow the action as desired. A record is made of the movement and, for subsequent exposures on the same film, the record controls the camera movement, matching the original relation between the camera position and picture frame during these subsequent shots.[15]

In France two new lenses were announced. "Retrofocus," a very short focus lens designed so as to permit attachment and use on normal 35-mm cameras, and "Erax," a highly corrected lens developed by Société Kinoptik in which the graduation of the aperture of the diaphragm is proportional.

The Eclair Camerette, introduced in the United States from France in 1949, now has a companion model, the "Cameflex," which takes 35-mm and 16-mm film interchangeably (Fig. 1).[16,17]

The "Aquaflex," shown in Fig. 2, was introduced in the United States in 1950, the first one being used by the United States Navy. Essentially, it is a standard 35-mm Camerette with a specially designed magazine in an underwater blimp which permits external stopping and starting, speed control, focus and diaphragm changes.

A compressed-air cylinder attached to the underwater housing, working on a demand valve, maintains an internal pressure of 3 psi above the external pressure, irrespective of the depth to which the camera is submerged. Stabilizing fins allow the camera to be moved through the water smoothly. The camera and housing weigh about 100 lb when out of the water. Great flexibility of operation is attained by using diving equipment with self-contained air supply for the operator. While propelling himself and the camera by means of swim fins attached to his feet, the cameraman, unaided, can maneuver the camera and operate aperture and focus controls. Smooth travel shots, following divers or native fish down to a depth of 80 ft, have been shown before the Society.[16]

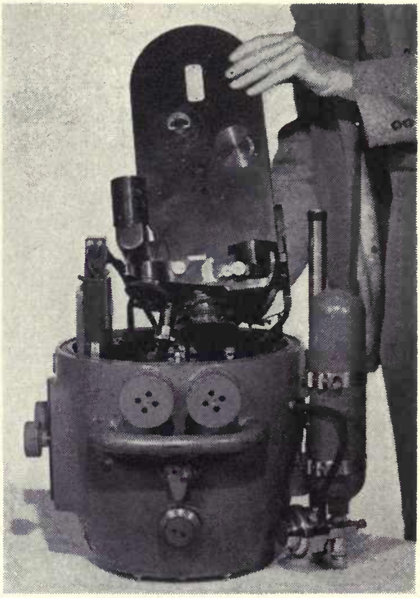


Fig. 2. The Aquaflex underwater photographic unit.

35-Mm Sound Recording

The year 1950 has seen noteworthy progress in the application of magnetic recording to motion picture production. The extent of the application has varied among the producers from cautious planning and preliminary experimentation, with the view of future conversion, to complete conversion to magnetic recording on all production and music recording work.

While many advantages with respect to quality of production, maintenance and operation of equipment, and conservation of film raw stock accrue from the use of magnetic recording, the over-all recording operation, from the original recording of dialogue and music to the production of the final release print, has been considerably complicated. As a result, many of the extensive claims of great economies to be effected by the use of magnetic recording have been considerably modified and conversion programs are now more in the nature of plant modernization. The great demand for smaller and lighter portable equipment for location, has been, possibly, the strongest influence in affecting the choice of magnetic recording, as magnetic-recording equipment has been the answer to this problem.

Since April 1, 1950, all Paramount production, both in the studio and on distant location, has been done on super-portable recording channels, weighing 65 lb and using $17\frac{1}{2}$-mil recording stock[18] (Fig. 3).

New portable magnetic-recording systems for 35-mm, $17\frac{1}{2}$-mm or 16-mm film, featuring compact, light weight construction, were introduced by Westrex, and are now in wide use in studios both here and abroad[19] (Fig. 4).

The use of magnetic equipment and re-recording has gained momentum. It has become the practice in a number of studios to record rehearsals on magnetic film. A good "rehearsal" becomes a "take" and unsatisfactory

"rehearsals" are erased. The "take" can be reviewed at any convenient time and then transferred to photographic film for release printing. In this connection, a multitrack magnetic equipment has been used to good advantage. This equipment records one, two or three tracks on the same film strip on which music, speech or sound effects, or any combination thereof, can be recorded with the same relative volume variations as they have in the finished product (Fig. 5). The benefits of this equipment, as experienced by Columbia Studios, are as follows:

It saves track storage space by a factor of about 10 to 1.

It reduces the cost of foreign versions by 50%.

It provides a ready means of furnishing duplicate release negatives as needed.

It provides a convenient source of material for television versions "minus music" and it provides a source from which dialogue, music and effects can be rebalanced in the dubbing of 16-mm versions.

Fig. 3. The Ryder portable magnetic sound recording unit.

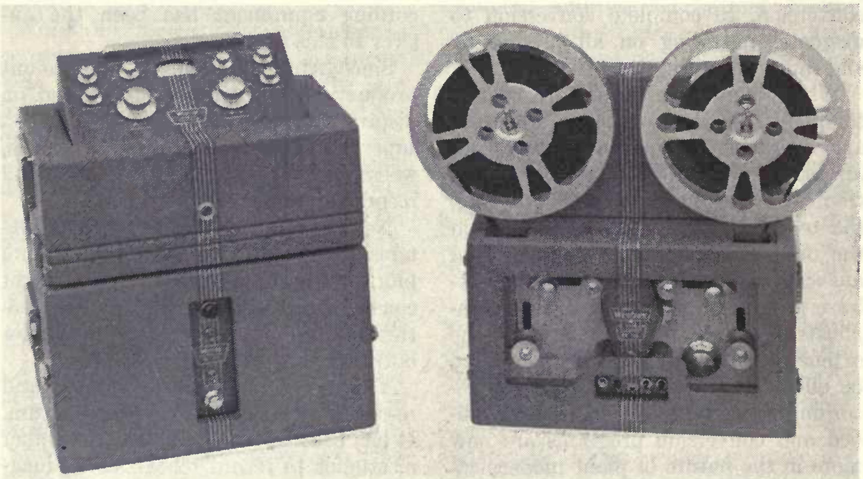


Fig. 4. Westrex portable magnetic sound recording system.

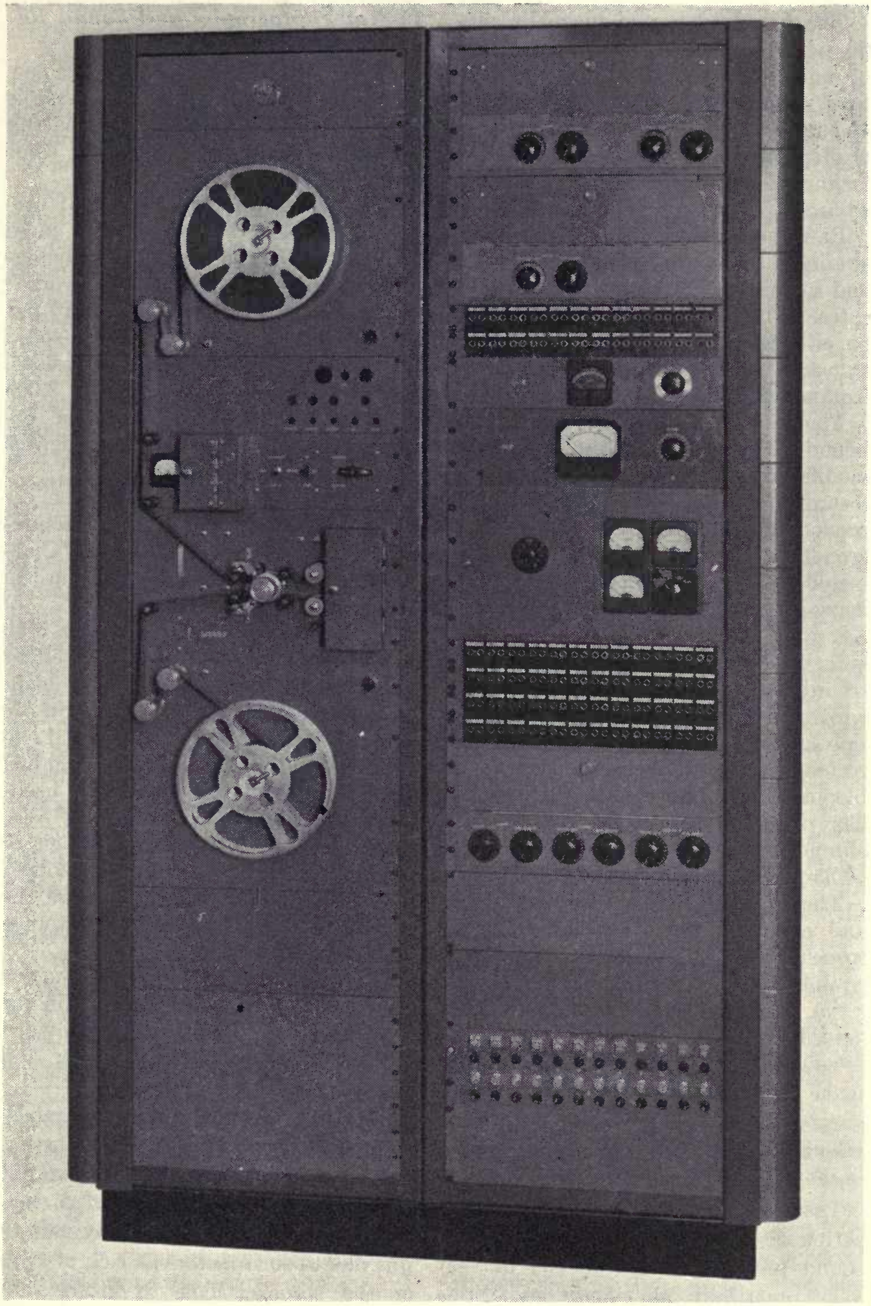


Fig. 5. RCA 35-mm 3-track magnetic recorder.

The increased use of magnetic production recording, together with a lack of suitable means of editing this material, has resulted in the development and use of equipment to make direct-positive photographic duplicates of the magnetic recordings for use by film editors.

Re-recording is being done in some studios directly from magnetic tracks, and in some, from photographic duplicates. Photographic duplicates may be either direct positives or electrical transfers to a photographic negative from which re-recording prints are made.

The Signal Corps Studios, Long Island City, N.Y., have applied several modifications to standard magnetic recording systems, which provide improved operating efficiency as well as economies in time and material. These include facilities for: (1) stopping, reversing and restarting recorder, re-recorder and projector in interlock, and (2) silently changing over from record to playback, or vice versa, while running. Thus, errors in narration and re-recording jobs may be corrected without rethreading, splicing or blooping the film. Also, this studio has perfected a method for lip-synchronous production which makes use of 35-mm magnetic loops.[20]

The year 1950 has seen continued and extended use of nonsynchronous sprocketless-type magnetic recording equipments, particularly in the field of radio transcription. There have been described in the Journal a number of schemes that have been developed to make these equipments operate synchronously with picture film for use in television and for cue-track recording.[21,22,23]

Last year also saw the use of low-shrinkage safety-base film extended to sound recording. By the end of the year practically all photographic recording was being done on acetate-base stock.

16-Mm Photography and Sound Recording

Ansco has placed on the market a new 16-mm color duplicating film. Ansco's new film type 238 is designed for making duplicates with soft gradation color originals.[24]

The Journal for January 1951 carries a complete bibliography of more than 600 items on high-speed photography covering all phases of the work.[25]

The Naval Ordnance Laboratory has developed techniques in the high-speed photography of underwater explosions. Pictures ranging from 2,000 to 3,000 frames/sec have been made of explosions of charges up to 1 lb, at depths down to 2 miles.[26]

Early in 1950 a new 100-ft-film capacity, 16-mm single-system sound-recording camera called the "Cine-Voice" was introduced by the Auricon Division of Berndt-Bach, Inc., of Hollywood, Calif. It is available with a galvanometer for recording either variable-area or variable-density high-fidelity sound track to SMPTE Standards. The camera weighs only 12 lb and the entire equipment, including amplifier, microphone, cable, headphones, accessories and carrying case, weighs 34 lb. It operates from either constant speed or synchronous motors. A portable power supply to drive the camera from an ordinary 6-volt storage battery is also available.[27]

Film phonographs embodying the fine motion and wide range inherent in the new magnetic recorders were provided for studio re-recording, dubbing and certain television applications.

Magnetic ¼-in. tape recorders gained popularity for many types of industrial and commercial purposes but were not generally accepted for motion picture recording. This lack of acceptance was due to such factors as lack of faith in the sprocket hole to insure synchronization, desire for standard speeds and desire for film that could be run

on existing playback and editing equipment.

The RCA type RT-11A magnetic tape recorder was built for professional service and is being used widely in the broadcasting and television fields. It has also found limited acceptance in motion pictures for recording projection takes.

Comparatively little use was made of 16-mm magnetic film although recorders were available.

Reeves Soundcraft Corp. introduced a service for edge-coating 16-mm raw stock or developed film with magnetic material to permit the use of magnetic sound tracks with 16-mm prints. Excellent sound reproduction from such prints was demonstrated at the fall convention using a modified projector.

J. A. Maurer, Inc., demonstrated a new multiple-track 16-mm sound-recording system that reduces distortion resulting from nonuniformity of the projector sound-scanning light beams.

The Magnagram Corp. of North Hollywood, Calif., has announced a new subminiature field unit, the F-102 magnetic film recorder. Available in 16 mm or 17½ mm, the unit is light in weight (38 lb for two cases) and extremely compact. Film capacity for either is 400 to 1200 ft of magnetic stock.

35-Mm Picture and Sound Reproduction

The activities of the Screen Brightness Committee in obtaining accurate information on a group of 100 theaters throughout the country has already had an effect on the motion picture studio laboratories where the preliminary information is being used to determine if changes should be made in print density.

In at least one studio it was found desirable to increase set lighting levels slightly in order to improve the projection quality of the prints.

This work promises to bring about a much better correlation between production and exhibition both as to print quality and projection conditions.[28,29]

At least two new mirror-type carbon-arc projection lamps have been described. These units feature fast optics, arc-positioning devices, forced air control of exhaust gases and new methods of automatic arc control.[30,31,32]

In the field of control of heat in the projection optical train, there have been a number of installations of units with heat-absorbing glass filters and others with compressed air blowing against the film. In addition, considerable work is being done experimentally and in field tests with treated mirrors and optical train filters of the interference type.[33]

A new all-plastic screen made of Firestone "Velon" plastic and known as RCA Snowhite Evenlite vinyl screen is illustrated in Fig. 6. The material is 0.012 in. thick, weighs ⅑ psi and is said to be sag proof. It is pigmented with titanium dioxide and surface embossed for high efficiency and diffusion. It is also flameproof, mildew proof and unaffected by heat, cold or moisture. The surface is rugged and can be cleaned by washing, soft brush or vacuum cleaner.

A new Walker high-intensity screen is made of plastic in which no vinyl is used. The metallized surface is made up of elliptical forms which spread the light fanwise to control reflection. It is recommended for theaters with wide-angle viewing conditions, but with no more than a 12-deg projection angle. It is claimed that the control of stray light improves contrasts and results in better apparent definition.

Cinerama, a system of exhibiting three frames of film in a curved panorama, has been demonstrated. It is stated that, while the inventor does not claim stereoscopic results from a strictly technical standpoint, the effect is one of super reality. The system includes the use of several sound tracks for projection of stereophonic sound.[34]

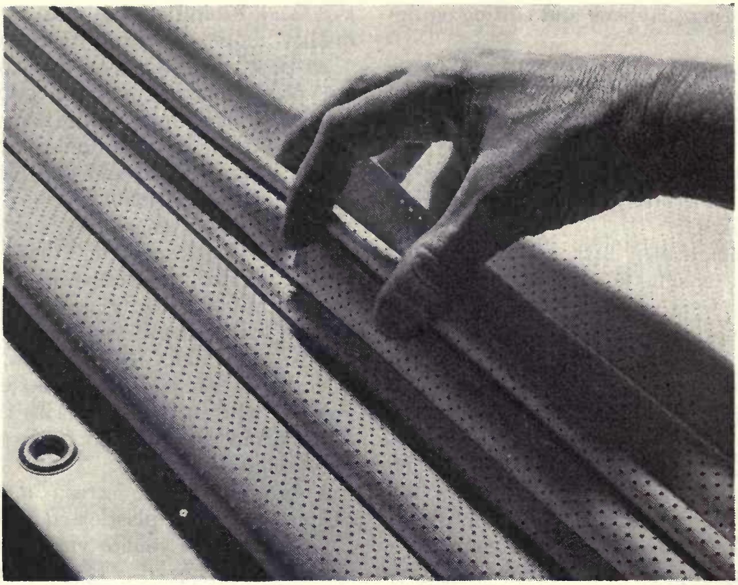


Fig. 6. RCA Snowhite Evenlite vinyl screen.

16-Mm Picture and Sound Reproduction

Nineteen-fifty has been a year of marked improvement in the whole 16-mm process, inspired mainly by television. A number of professional-type 16-mm projectors have been made available, with performance approaching 35-mm standards.

Eastman Kodak Co. has announced and demonstrated a heavy-duty 16-mm professional projector which uses the same type of intermittent sprocket movement as in 35-mm professional projectors.[35,36] (Fig 7).

The International Projector Corp. has described a sturdy, high-quality 16-mm projector designed to meet U.S. Navy Bureau of Ships Specification CS-P-41A.[37]

Mitchell Camera Corp. announced a new "giant" 16-mm professional projector which offers optional high-intensity carbon arc or incandescent lamp illumination. It was designed to function with standard 35-mm sound equipment.[38]

Approximately 1,400 16-mm sound motion picture projectors, built to comply with the high performance required by the Joint Army-Navy Specification JAN-P-49, were put into service by the armed forces during the past year. The Navy Motion Picture Film Exchange, Naval Shipyard, Brooklyn, is employing these projectors to evaluate and accept all 16-mm prints of entertainment films procured by the Navy. The projectors are used in accordance with the Society's "Tentative Recommendations for 16-Mm Review Rooms and Reproducing Equipment."[39] The prints are screened with both lead sulfide- and caesium-type photoelectric cells to insure that there will be no material difference in sound reproduction when the prints are presented to the Fleet on either type of equipment.[40]

Television

Many people have said that television came of age in 1950. There is considerable truth in this statement and it may be traced largely to the fact that the industrial companies of America have recognized television's tremendous sales appeal and have consequently devoted large sums of money to the production of shows intended for release in many cities throughout the nation. Fortunately it has been possible to cover many of these cities, and consequently a large percentage of the television audience, with live programming via the facilities of the American Telephone and Telegraph Co. The so-called nonconnected cities are still covered by the use of video recordings, the quality of which has improved drastically during the year.

The availability of higher budgets has allowed the television networks and studios to use more care in production techniques and staging. Notable improvements have resulted, for example, in lighting, costuming and make-up, the use of process screens, and in a

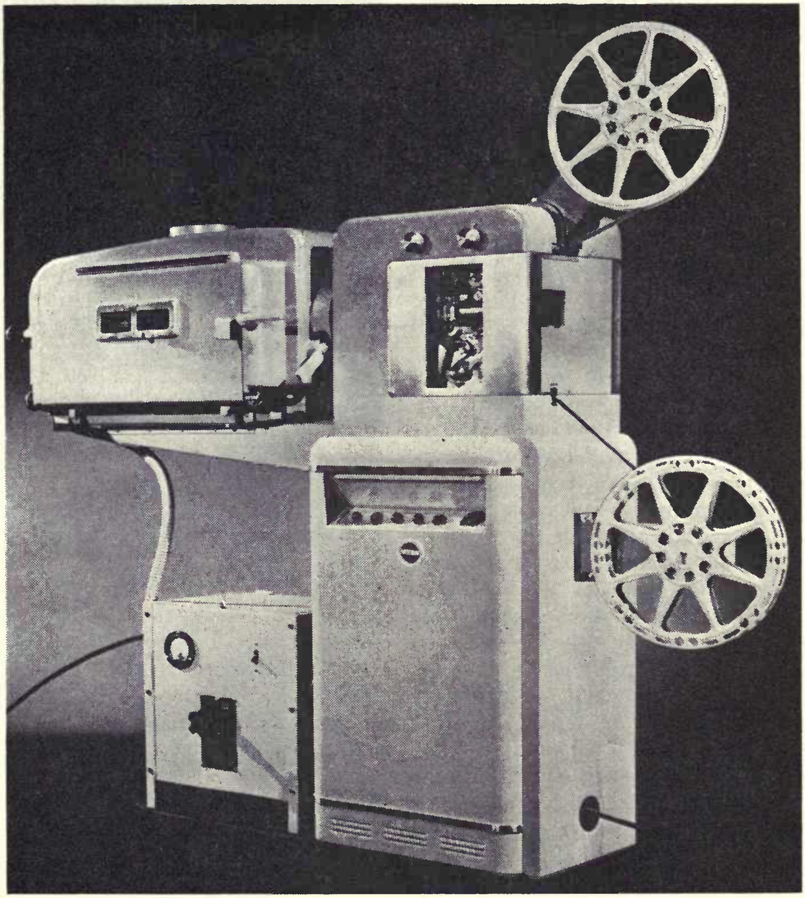


Fig. 7. Eastman 16-mm projector, model 25, with arc lamp.

general recognition of how the limitations of the system must always be carefully considered in the staging of a studio production.[41–46]

The motion picture industry's many techniques, developed over a period of years, are now being used more and more in television studios, although it has been found that these motion picture techniques must be applied with extreme care because of the differences between the mediums.

The marked change in television delineated above has required a great expansion of many of the television stations and studios throughout the country. There seems to be a trend toward more and more space and the industry has concluded that facilities at least approaching in size those of the motion picture production lot will ultimately be required. There have been several purchases of large acreages on which numerous buildings will operate in order to handle the production requirements which are foreseen.

The Use of Film. Direct photography for television shows has increased during the year. A number of production companies have operated specifically for this purpose and with considerable success. Most such productions have been of half-hour shows, some of which have been serialized. Both 16-mm and 35-mm cameras have been employed, although the trend at the moment seems to be the favor of the latter, in spite of the fact that many of the television stations are forced later to use 16-mm reduction prints. Of the top TV network shows on the air at the close of 1950, approximately 20% were on film.[47–50] As recorded in the Progress Report for 1949, there has been some interest in the technique of so-called simultaneous filming of live television shows; however, this technique is still not widely used.

The demand for special prints reflects the growing practice in the television industry. Most large stations on television networks have established standards for print characteristics which give optimum television quality.[51]

Background projection as an adjunct to live programming is becoming more common.

The technique of film projection for television transmission has received a lot of study. A method of improving the image quality by using filters in the projector to remove infrared radiation, and by filtering edge- and bias-light in iconoscope film cameras has been proposed. As a result of the interfering effects of light level and tube variation, this procedure is still controversial.

The Eastman Kodak Co. has manufactured a new 16-mm television projector, model 250, which is intended to give superior performance for film chains. The projector operates on the conventional 5% application principle, but offers improved picture steadiness, brightness and definition as well as excellent sound quality. Facilities are provided for continuous projection of a single frame, or regular projection with remote operation (Fig. 8).

Video Recording. Video recording progress during 1950 has been very great. In fact, it is generally agreed among those intimately involved with this technique that within the limits of the television system as established by the FCC and as further laid down by equipment limitations, the recording system can take down what is delivered to it. Phrased another way, it is conceded now that the operation inside the studio is the point where the recording is made or broken. Unfortunately, many television shows are rehearsed so little that certain fundamental rules that affect the quality of a television recording are violated. Whenever this is done the results are extremely unfortunate. To be more specific, it is necessary that lighting be handled with extreme care. A lighting contrast of

no more than 3 or 4 to 1 should be maintained at all times. In addition, since generally more than one camera is used in a television studio the camera angles must be carefully observed so that lighting will be adequate regardless of which camera is in operation. Furthermore, camera levels must be controlled in order to maintain a balance between cuts. It is much more important that this balance be observed when television recording than when producing a show which will be released only as a live show.

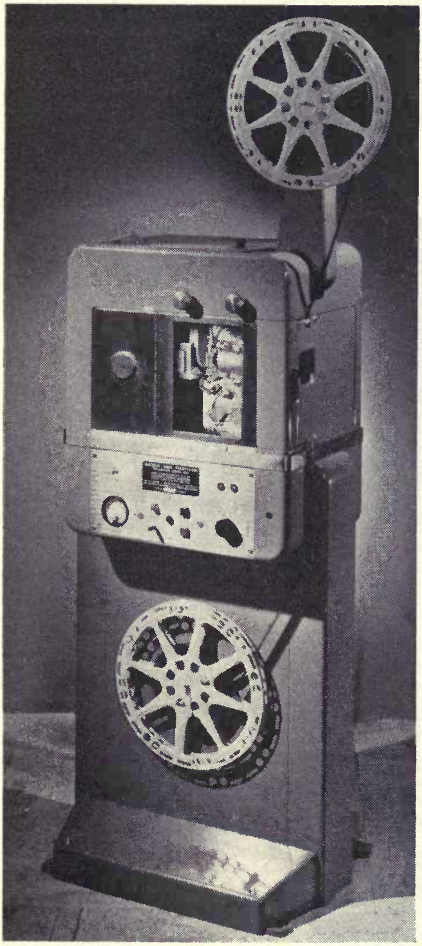


Fig. 8. Eastman 16-mm television projector, model 250.

The sound portion of television recordings has been handled in numerous ways by the various studios throughout the country. Some of the best sound has been obtained through the use of tape recording which is synchronized electrically or by the use of perforated tape. Both single and double system recordings are still employed.

A new complete chain of equipment for either television recording or large-screen television projection by an intermediate film system has been developed by General Precision Laboratory, Inc.[52] This equipment consists of a high-quality monitor, 16-mm recording camera, rapid film processor and projector. The monitor is provided with electronic blanking for the frame-rate conversion and gradient correction circuits. The camera has the rapid pull-down required of all television recording cameras and a high-quality sound-recording head. The rapid film processor can be used directly with the camera or separately.[53]

During 1950 the Navy Special Devices Center continued their studies of television as a method of mass training in the Armed Services. The psychological studies to measure the relative effectiveness of television training showed conclusively a definite superiority over direct classroom instruction. In the spring of 1950 the Signal Corps Photographic Center collaborated with the Special Devices Center to present eight weeks of one-hour programs over a ten-city CBS network to reach approximately 5,000 reserves.

In continuing its investigations of new television equipment for Navy use, work was advanced toward the final design of a prefabricated classroom which could be mass produced in time of emergency.

The Navy experiments have attracted wide attention and have helped

focus the interest of educators on television training. The recent FCC hearings on allocations for educational television stations is concrete evidence of this aroused interest.

The first acceptable motion picture photography of color television kinescope images was performed by the Navy, combining techniques developed for recording of radar PPI scopes and television kinescopes. A modified professional 16-mm camera and a specially designed high-speed 25-mm $f/0.7$ lens were employed.

Television Remotes. The tremendous impact of television as a means of taking the home audience to the scene of a remote, whether it be a sporting event or another type of special feature, has been demonstrated time and again during 1950. In fact, the effect of television on the local audience at a sporting event has created a national controversy. The "gate" at football and baseball games has been increased, decreased and unchanged—depending entirely upon whom you talk to and in what part of the country your conversation takes place. However, that the public enjoys the telecasts of such events is without controversy.

Theater Television. In the early months of 1950, RCA completed the design of its first commercial theater television equipment, the Model PT-100 (Fig. 9). This is a direct-projection system employing a projection kinescope and Schmidt optics. A pilot run was placed in production and twelve equipments were delivered and

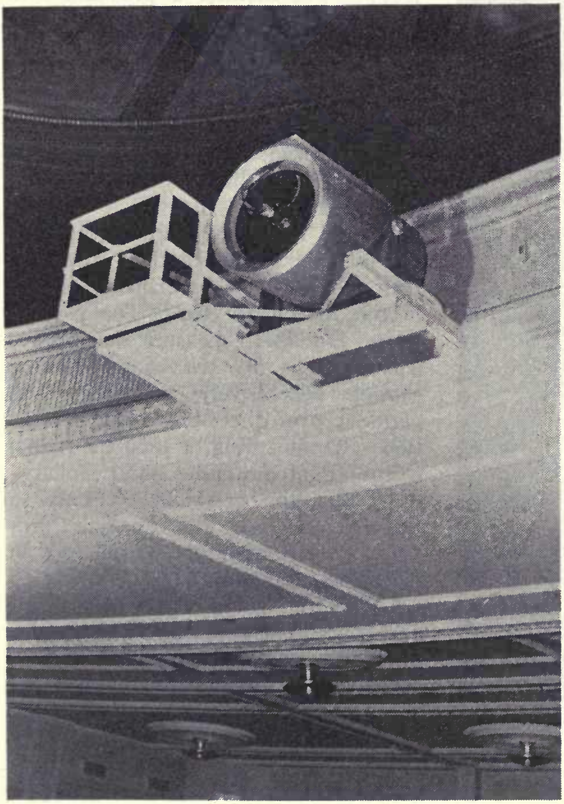


Fig. 9. RCA theater television projector.

installed in theaters in Providence, Albany, Binghamton, Brooklyn, the Bronx, Queens Village, Chicago and Los Angeles in time for the start of the fall football season.

At the Theatre Equipment and Supply Manufacturers Convention in Chicago in October, General Precision Laboratory announced and demonstrated an intermediate film theater-television equipment using 16-mm film. This unit was later demonstrated at the Theatre Owners of America Convention in Houston and at the SMPTE Convention at Lake Placid.[52,53]

United Paramount Theaters, Inc., installed Paramount's intermediate film equipment in one of its Detroit theaters just prior to the start of the football season.

The Eastern theaters have all shown a series of football games carried by the television broadcasting networks. In spite of the fact that the theaters were attempting to sell entertainment that was available free on home television the over-all boxoffice results were highly favorable and improved as the season advanced.

Several of the theaters are using television news programs on a daily basis to replace a regular film newsreel. This has been very popular because of the timeliness of the news.

United Paramount Theaters obtained the exclusive television rights to the University of Illinois and University of Michigan football games and showed them in theaters in Chicago and Detroit. Attendance at these first exclusive showings was very satisfactory with sellouts toward the end of the season.

A group of Eastern theaters is working on exclusive programming which they hope to get under way before the year is out.

Twentieth Century-Fox is moving rapidly toward setting up a large network of theaters in Southern California to be programmed on a closed-circuit basis from a company-owned television studio.

The French Company, Debrie-Radio-Industrie, made a demonstration at the Madeleine Theater, Paris, of a system of cathode-ray tube photography and rapid development on 16-mm film which placed the picture on a full-size theater screen 80 sec after the transmission of the television picture.

It was reported that Twentieth Century-Fox has secured the exclusive use of the Swiss Eidophor system for theater television. This system provides excellent image clarity and screen brightness and uses a high intensity carbon arc as a light source.[54,55]

The Committee

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References

1. "Conversion to safety film 85% complete," *Internat. Proj.*, p. 26, July 1950.
2. W. F. Kelley and W. V. Wolfe, "Technical activities of the motion picture research council," *Jour. SMPTE*, vol. 56, pp. 178–196, Feb. 1951.
3. "New Eastman color film tested by Hollywood studios and film labs," *Amer. Cinematographer*, vol. 31, p. 95, Mar. 1950.
4. A. M. Gundelfinger, "Cinecolor three-color process," *Jour. SMPTE*, vol. 54, pp. 74–86, Jan. 1950.
5. V. B. Sease, "Du Pont's new color film," *Amer. Cinematographer*, vol. 30, p. 240, July 1949.
6. A. B. Jennings, W. A. Stanton and J. P. Weiss, "Synthetic color-forming binders for photographic emulsions," *Jour. SMPTE*, vol. 55, pp. 455–476, Nov. 1950.
7. John G. Capstaff, "An experimental 35-mm multilayer stripping negative

film," *Jour. SMPTE*, vol. 54, pp. 445–453, Apr. 1950.
8. "New Technicolor system announced," *Amer. Cinematographer*, vol. 31, p. 354, Oct. 1950.
9. Leigh Allen, "New Technicolor system tested by directors of photography," *Amer. Cinematographer*, vol. 31, p. 414, Dec. 1950.
10. Peter Mole, "Will there always be a need for carbon arcs?" *Amer. Cinematographer*, vol. 32, p. 50, Feb. 1951.
11. Motion Picture Studio Lighting Committee Report, *Jour. SMPTE*, vol. 56, pp. 205–213, Feb. 1951.
12. Frederick Foster, "Economy lighting with photofloods," *Amer. Cinematographer*, vol. 31, p. 10, Jan. 1950.
13. Wayne Blackburn, "Study of sealed beam lamps for motion picture set lighting," *Jour. SMPTE*, vol. 55, p. 101–112, July 1950.
14. Arthur L. Smith, "Economy in small-scale motion picture lighting," *Jour. SMPTE*, vol. 55, pp. 180–188, Aug. 1950.
15. O. L. Dupy, "A motion repeating system for special effect photography," *Jour. SMPTE*, vol. 54, pp. 290–294, Mar. 1950.
16. R. R. Conger, "U.S. Naval underwater cinematography techniques," *Jour. SMPTE*, vol. 55, pp. 627–634, Dec. 1950.
17. Frederick Foster, "A new Eclair Camerette takes either 35-mm or 16-mm film," *Amer. Cinematographer*, vol. 32, p. 92, Mar. 1951.
18. Loren L. Ryder, "Motion picture studio use of magnetic recording," *Jour. SMPTE*, vol. 55, pp. 605–612, Dec. 1950.
19. C. R. Crane, J. G. Frayne and E. W. Templin, "Professional magnetic recording system for 35-, 17½- and 16-mm films," *Jour. SMPTE*, vol. 56, pp. 295–309, Mar. 1951.
20. George Lewin, "Special techniques in magnetic recording for motion pictures," paper presented on May 4 at 1951 SMPTE Convention in New York City.
21. D. G. C. Hare and W. D. Fling, "Picture-synchronous magnetic tape recording," *Jour. SMPTE*, vol. 54, pp. 554–566, May 1950.
22. R. H. Ranger, "Sprocketless synchronous magnetic tape," *Jour. SMPTE*, vol. 54, pp. 328–336, Mar. 1950.
23. Walter T. Selsted, "Synchronous recording on ¼-in. magnetic tape," *Jour. SMPTE*, vol. 55, pp. 279–284, Sept. 1950.
24. "Ansco announces new 16-mm color duplicating film," *Amer. Cinematographer*, vol. 31, p. 204, June 1950.
25. "Bibliography on high-speed photography," *Jour. SMPTE*, vol. 56, pp. 93–111, Jan. 1951.
26. Paul M. Fye, "The high-speed photography of underwater explosions," *Jour. SMPTE*, vol. 55, pp. 414–424, Oct. 1950.
27. "Cine-voice demonstrated for A.S.C.," *Amer. Cinematographer*, vol. 31, p. 232, July 1950.
28. Screen Brightness Committee Report. *Jour. SMPTE*, vol. 54, pp. 756–757. June 1950.
29. Charles W. Handley, "An optical alignment check system," *Internat. Proj.*, vol. 25, p. 17, June, 1950.
30. Arthur J. Hatch, "The differential carbon-feed system for projection arc lamps," *Jour. SMPTE*, vol. 56, pp. 86–92, Jan. 1951.
31. Edgar Gretener, "Physical principles, design and performance of the vent-arc high-intensity projection lamps," *Jour. SMPTE*, vol. 55, pp. 391–413, Oct. 1950.
32. Edgar Gretener, "The ventarc H.I. carbon 'blown' arc; a new concept," *Internat. Proj.*, vol. 25, p. 13, July 1950.
33. G. J. Koch, "Interference mirrors for arc projectors," *Jour. SMPTE*, vol. 55, pp. 439–442, Oct. 1950.
34. "Cinerama; super-movies of the future," *Internat. Proj.*, vol. 25, p. 10, Nov. 1950.
35. "Intermittent sprocket feature of new Eastman heavy-duty 16-mm sound projection," *Amer. Cinematographer*, vol. 31, p. 204, June 1950.
36. Edwin C. Fritts, "A heavy-duty 16-mm sound projector," *Jour. SMPTE*, vol. 55, p. 425–438, Oct. 1950.

37. G. T. Lorance, F. B. Dibble, and H. J. Reed, "A sturdy high-quality 16-mm projector," *Jour. SMPTE*, vol. 54, pp. 171–182, Feb. 1950.
38. "Mitchell announces new professional 16-mm projector," *Amer. Cinematographer*, vol. 31, p. 134, Apr. 1950.
39. "Tentative recommendations for 16-mm review rooms and reproducing equipment," *Jour. SMPTE*, vol. 56, pp. 116–122, Jan. 1951.
40. James A. Moses, "Trends of 16-mm projector equipment in the army," *Jour. SMPTE*, vol. 55, pp. 525–535, Nov. 1950.
41. Richard S. O'Brien, "CBS television staging and lighting practices," *Jour. SMPTE*, vol. 55, pp. 243–264, Sept. 1950.
42. H. M. Gurin, "Lighting methods for television studios," *Jour. SMPTE*, vol. 55, pp. 576–589, Dec. 1950.
43. Leigh Allen, "Adapting motion picture lighting to television," *Amer. Cinematographer*, vol. 31, p. 162, May 1950.
44. Wayne R. Johnson, "An experimental electronic background television projection system," *Jour. SMPTE*, vol. 55, pp. 60–66, July 1950.
45. Herb. A. Lightman, "Filmed inserts and special effects aid live TV shows," *Amer. Cinematographer*, vol. 31, p. 124, Apr. 1950.
46. R. A. Lynn and E. P. Bertero, "Process projection of film for TV," *Internat. Proj.*, vol. 25, p. 8, Oct. 1950.
47. Eastman Kodak Co., "Production of films for television," *Amer. Cinematographer*, vol. 31, p. 12, Jan. 1950.
48. Eastman Kodak Co., "Producing films for television," *Amer. Cinematographer*, vol. 31, p. 47, Feb. 1950.
49. Herb. A. Lightman, "Economy prime factor in producing films for TV," *Amer. Cinematographer*, vol. 31, p. 377, Nov. 1950.
50. Jerry Fairbanks, "Motion picture production for television," *Jour. SMPTE*, vol. 55, p. 567, Dec. 1950.
51. Charles L. Townsend, "Specifications for motion picture films intended for television transmission," *Jour. SMPTE*, vol. 55, pp. 147–157, Aug. 1950.
52. R. L. Garman and B. Foulds, "Some commercial aspects of a new 16-mm intermediate film television system," *Jour. SMPTE*, vol. 56, pp. 219–226, Feb. 1951.
53. J. S. Hall, A. Mayer and G. Maslach, "A 16-mm rapid film processor," *Jour. SMPTE*, vol. 55, pp. 27–36, July 1950.
54. *American Cinematographer*, vol. 32, p. 30, Jan. 1951.
55. E. Labin, "The Eidophor method for theater television," *Jour. SMPTE*, vol. 54, pp. 393–406, Apr. 1950.

69th Semiannual Convention

ATTENDANCE at the New York Convention set an all-time record with 659 registrations logged between Monday morning and Friday afternoon, April 30—May 4. It was a full program comprised of 60 technical papers, six engineering committee reports, generous discussion in many of the sessions, and 15 engineering committee meetings held during the week.

On Monday morning registration got off to a slow start but by noon the registration staff (Bill Kunzmann, Erv Geib, George Gordon and Paul Ries) were knee-deep in cash customers. There was a heavy turnout for the Get-Together Luncheon. Peter Mole officially opened the Convention with some pertinent and potent remarks which are published below, immediately followed by the luncheon address by Nathan D. Golden, Director of the Motion Picture Photographic Products Division of the NPA.

Get-Together Luncheon Remarks by President Mole

SEVERAL TIMES since I became President I have been asked whether or not the Society of Motion Picture and Television Engineers can carry water on both shoulders—meaning of course, is it possible for the Society to serve the needs of both motion pictures and television at the same time. My answer is that the Society has been and is now serving these related interests successfully. It intends to continue doing so in the future with increasing effectiveness. In the eyes of the engineer no conflict exists between motion pictures and television because both are mutually related methods of pictorial communication—they both provide pictorial rendition of action that has occurred at another place or at another time. Because the two are very closely related, I believe their techniques and their processes can be applied interchangeably on a broad scale, resulting in joint contributions of great value. The change of the Society's name a year ago to include the word "television" was formal recognition by the engineers of these interrelationships.

Just as television has come to rely heavily on motion picture films and on the techniques of motion picture studio production, so must the motion picture producer and exhibitor seek out, experiment with, and adopt new techniques that appear to have commercial possibilities. This calls for courage and imagination unclouded by the fears which the present economic conditions have produced within the motion picture industry.

Remembering the economic boost that followed the introduction of sound, many people have said recently that great new technical strides must be taken at once to keep the motion picture industry prosperous. In my opinion the present state of affairs is quite the contrary, however, because technical contributions already at hand are far ahead of the industry's willingness to adopt them. The lack of interest in commercializing these developments now may have the effect of applying a brake on future technical growth. If allowed to continue, it could become a demoralizing influence upon our engineers and research workers. I refer not only to the early application of television by the motion picture industry but also to: the potentialities of the increased use of color, multiple sound tracks, wide angle pictures and stereoscopy. Any of these things might recapture the interest of the moviegoing public.

In our Society we have been able to unite engineers from the motion picture field with engineers from radio and from other fields into a unified organization in which one group complements the other. Has the same result been accomplished within the motion picture industry? I am afraid it has not. Do the engineer, producer and exhibitor work hand in hand? The answer is an unequivocal No.

The past success of the motion picture industry was made possible by men who had the intuition to foresee its great

potential future and were willing to risk time and money in exploiting it. It is quite possible that this same pioneering spirit will be needed again before the technological advancements already known are properly applied.

Unfortunately, in many instances the men who head the motion picture industry and who should translate invention into commercial reality have become so economy minded that their first question concerning a new technical process or product is "What will it cost?" and not "How can it benefit this industry?"

We in the Society of Motion Picture and Television Engineers are constantly improving the technical elements of the pictorial rendition of action. It is now up to the producers and exhibitors of motion pictures to take advantage of our technical developments and to continue their business as the most effective medium of mass education and entertainment yet devised.

Address by Nathan D. Golden, Director of the NPA Motion Picture Photographic Products Division

I IMAGINE that a good many of the scientists and engineers here feel that the actions and orders of the National Production Authority are aimed at just about everybody in the industry except yourselves. Of course, the people who are most directly affected by such orders are controllers, purchasing agents and production managers. The NPA Orders generally concern limitations on the procurement of raw materials involving a reduction in the number of products which can be produced.

Now, what I hope to get across to you gentlemen is the fact that, while others in the industry may actually put into effect the changes required by the NPA orders, engineering has an absolutely vital job in curing the problems created by material scarcities, which have largely made necessary the issuance of those NPA orders. That job is as vital to the industry as it is to the defense effort and to the nation's economy.

Before I explain in detail what we believe is the responsibility of this Society and each of its members in the defense mobilization program, I would like to review briefly just what has been going on since the program got under way.

Last September, when Congress passed the Defense Production Act of 1950, employment was practically at an all-time peak. The national personal income was climbing to over two hundred twenty-three billions of dollars for the year. Most consumer products were coming off the assembly lines in volumes unsurpassed in history. Home building was at a new level. Naturally, when the impact of the military demands was imposed on top of this wide-open economy, dislocations of production and distribution of many consumer goods immediately resulted.

From the outset of defense mobilization, the Government was faced with two definite jobs: first, to give the green light to all defense programs and to see that materials and productive capacity were made available to meet the delivery schedules; and second, to halt inflationary trends and, equally important, to keep the domestic economy strong through encouraging maximum civilian production with a minimum of disruption to American manufacturers.

To meet these objectives, the NPA promptly issued regulations establishing the percentage of a base-period production allowed each manufacturer. Other regulations promoted the equitable distribution of available supplies of such basic materials as steel, copper, zinc, tin, aluminum, textiles, rubber and certain chemicals. Subsequently, the constantly increased military demands have made it necessary to curtail more severely the manufacture of hundreds of end-products considered less essential to our economy.

Of course, practically all manufacturers have been affected in some degree by these general cutbacks—some have been severely hit. Wherever possible, hardship cases have been adjusted to protect business, particularly small business, and to minimize unemployment during this transition period. Defense orders and subcon-

tracts now totaling billions of dollars should help to relieve this situation soon. Meanwhile, the diversion of materials, end-products and facilities from normal civilian consumption to defense use cannot be avoided. It is inescapable, and as time goes on further diversion in progressively greater amounts is clearly indicated.

Thus, as a result of world conditions, it has become necessary for everyone, both in Government and industry, to recognize the fact that there are not enough raw materials and productive capacity and manpower to maintain our expanded defense program on top of the same high level of civilian economy.

Conservation of Materials

The problem of obtaining materials is complicated by the fact that many major sources of raw materials are in parts of the world where conflict exists. In some significant cases, those sources are in countries whose national interests are such that they may not wish to, or may not be able to, supply us in the immediate future. For example, the major source for hog bristle is China; for certain grades of chromite, the USSR; for crude natural rubber, Malaya; for tin, Malaya; and for tungsten, China. Cobalt comes from the Belgian Congo, mica from India, nickel from Canada, and shellac and talc from India. You can readily appreciate the fact that under present conditions, some of these sources of supply are either substantially cut off, or could very well be cut off in the near future. For this reason, it has become very important that these limited supplies of raw materials be carefully allocated to support the defense program, to create stockpiles against any reasonably foreseeable emergency, and to maintain as high as possible a level of civilian economy.

All of this points up to one serious problem. For some considerable time in the future, it is going to be necessary for you engineers and scientists to find ways and means of using lesser amounts of critical material and to develop substitute materials in designing the products which your companies produce. We look upon this broad problem as *conservation* and consider it of sufficient importance to warrant adding to my staff within a few weeks a thoroughly qualified engineer, who will devote his full time to this subject. NPA's concept of conservation is divided into five categories: simplification, standardization, substitution, specifications, and salvage and scrap.

It is felt that whenever industry itself initiates conservation programs fitting into these categories industry will be more willing to abide by the necessary regulations. The citizens of the country who are producers, consumers and distributors —and often all three in one person—are the best regulators of their own interests. Voluntary standards arrived at by private industry largely obviate the necessity for Federal regulations.

Standardization Program

Now, as we all know, standardization is a function that costs money and must be paid for. Such costs are simply one expense of doing business. They are as much a routine and necessary business expenditure as legal counsel, advertising or market research. The ultimate benefit of voluntary standards to any one company depends upon the cooperate efforts of all parts of business and industry.

You may be interested in knowing that for a number of years, the Commodity Standards Division of the Department of Commerce has aggressively pursued the matter of simplification and has succeeded in effecting many simplified practice recommendations.

Here are a few examples of what has been done in this line. There were formerly 5,580 varieties of pipes, ducts and fittings for air-conditioning equipment, which by voluntary agreement were reduced to 1,225 (or a reduction of 78%). The number of different types of carbon brush terminals has been reduced from 1,500 to 48 (a reduction of 97%). In the case of 50-watt light bulbs, there were formerly nine different shapes, with or without various amounts of frosting, which were reduced to one (making a reduction of 89%). Two years ago there were 347 models of tank-mounted air compressors with ratings between ¼ to 10 horsepower; today there are only 12 models (a reduction of 96%). These are a few of the many accomplishments by this group,

which show what can be done on a voluntary basis, with close coordination between Government and industry.

The Society's Work

The Society of Motion Picture and Television Engineers is well known for its great accomplishments in the field of standardization. It has often been stated that the Standards Committee of the Society is the focal point of most of its efforts. There is no question that the industry would be in a chaotic condition today if this Society had not taken the initiative and obtained approval for the standards which are now largely recognized by the motion picture industry throughout the entire world.

The Society and each of its members must now accelerate this activity, with the objective of producing products equally as good as, or better than, those formerly made available, but using smaller quantities of critical materials. It is easy to argue that an irreducible minimum use of those materials already has been reached. However, so many new materials have come into being and been put to profitable use within the last few years, that this argument does not entirely hold water.

We find that metals which were curiosities a few years ago are now vital to our military programs. The new tools of warfare created by science, such as jet engines, guided missiles, and the like, are suddenly absorbing great amounts of metals for which we were just beginning to find beneficial industrial uses. I think it is fair to say that through aggressive study you can undoubtedly find ways and means of using many available materials in place of critical ones in ways that have not heretofore been considered.

Those programs which the Government has already started are being stimulated by the National Production Authority Conservation Coordinator, to re-examine all types of Federal specifications, with the goal of modifying them wherever possible to reduce the requirements for critical materials. Suggestions from industry in this program will, we are certain, prove to be invaluable.

With respect to salvage and waste, every manufacturer must make every possible effort to minimize this problem. We all know that time and again science and engineering have found ways to use what is considered waste material in one industry as the raw material for another. An intensification of this kind of activity is essential under present conditions.

As you know, for many years the Government has initiated programs for conservation of certain of our natural resources such as our forests. By instituting conservation programs and by planting new trees, it is possible to perpetuate the supply of lumber. Obviously, the same kind of program cannot be utilized in connection with our mineral resources.

Our mineral resources are not going to last forever. Normal civilian production continues to increase year after year. War and defense programs superimposed on our civilian economy every ten or twenty years add another serious drain.

We feel that conservation is a serious responsibility of societies such as yours. We feel that engineers and scientists in every manufacturing concern within the motion picture photographic industry ought to hit hard at this problem through studies and programs which will lead to the conservation of the important critical materials. This represents not only a service which the industry can perform for the national well-being; it is also an intelligent means of promoting the industry's well-being in a time of possible prolonged shortages.

And speaking of shortages, I can think of no better forum than yours to state that as of this moment there is no shortage of motion picture film. I will agree there has been an acute tightness in the supply and that it is difficult to secure delivery on the amount of film desired to build an excess inventory, but as to extreme shortage, there is none, regardless of statements to the contrary by undisclosed sources, who are not in possession of the true facts. Film suppliers and manufacturers inform me, and they should know, that they are still delivering comparable footage to their accounts paralleling 1950 purchases. Under such conditions one can ask no more. While it is true that it limits expansion for securing new business, business comparable to 1950 is better

than what might eventuate under a limitation order, or an allocation system.

The National Production Authority, as well as other Government agencies charged with the responsibilities of carrying out the defense program, earnestly requests your close cooperation so that as a team we can accomplish this objective, not only for the benefit of the country as a whole, but also in order that the motion picture photographic industry can protect its important position in our entire economy.

Papers Program

The extra effort put into advance planning of the Program has already paid tangible dividends. Bill Rivers, local Papers Vice-Chairman, Ed Seeley, Chairman, and a number of members of the Papers Committee started work on the spring program during the previous Convention, at Lake Placid. As a result, it took shape early enough for pre-convention publicity to be comfortably specific for a change. The Tentative Program was mailed to all members at an early date, and attendance was high.

Believing that the discussion of particular papers immediately after presentation should become a part of the printed version, but at the same time being dissatisfied with some previous efforts at recording the questions and answers, the Papers Committee and Board of Governors agreed on the purchase of a small "dictating machine" type of disc recorder. It was used in conjunction with the public address system during all sessions in the Georgian Room. Stenotypists were employed for the three other sessions.

The afternoon sessions included papers on film and processing with E. A. Bertram and F. J. Grignon as Chairman and Vice-Chairman. In the evening, there were papers on motion picture techniques with F. E. Cahill and E. M. Stifle, officiating. Members whose interests lay more in the direction of television were the guests of G. L. Beers at the Voice of Firestone television show staged in the Center Theater Studios of the National Broadcasting Company.

On Tuesday morning F. G. Albin and F. N. Gillette were in charge of the session on television recording and reproduction. At 1:00 P.M. 104 members and guests left by bus for the combined television session and tour of the Bell Telephone Laboratories at Murray Hill, N. J. A. G. Jensen, long active in theater television work of the Society was host to the visitors, on the tour which he and his staff had previously arranged. Dr. R. Bown, Director of Research, extended his greetings to the Society. Chairman of the session was G. L. Beers, and H. C. Millholland was Vice-Chairman. Following the last paper, the group left for dinner at a restaurant near by, returning to the Hotel Statler at about 10:00 P.M.

Wednesday was the busiest day of the week, with four technical sessions and the midweek Cocktail Party and Banquet and Dance. More than 250 members and nonmembers attended the morning and afternoon sessions on high-speed photography held in the Ballroom. Chairmen were M. L. Sandell and C. D. Miller; Vice-Chairmen were Earl Quinn and Kenneth Shaftan. Film projection and screen viewing factors were the subjects of the other two sessions held in the Georgian Room. Chairmen were W. W. Lozier and F. J. Kolb; Vice-Chairmen were A. J. Hatch and C. R. Underhill. To introduce the eating portion of the Wednesday evening festivities, President Peter Mole reminded the assembled party goers of the single-plank platform on which he was elected: "No speeches at banquets." The one paragraph remark was greeted with thunderous applause and followed by several hours of fun and frolic. The festivities broke up about 1:00 A.M.

There was a third group of high-speed photography papers on the Thursday morning session, which was, as usual, well attended in spite of much late revelry the preceding evening. Chairman and Vice-Chairman were Roy Wolford and Richard Painter. In the afternoon Pierre Mertz and Bill Deacy were Chairman and Vice-Chairman of a session including papers on a variety of problems and possibilities related to television.

Two sessions on Friday covered both magnetic and photographic sound recording. J. G. Frayne and R. G. Mann were Chairmen. W. F. Jordan was Vice-Chairman of the morning session.

Highlights, both real and contrived, of the five-day convention were recorded on 35-mm film with 35-mm magnetic sound by a production team under direction of Emerson Yorke. J. Burgi Contner was cameraman and Harry Braun was in charge of the RCA sound crew. Some members who attend the October convention in Hollywood will doubtless see themselves in an unfamiliar role.

Publicity

Leonard Bidwell, with the enthusiastic support of Helen Babigian of the Society headquarters staff, maintained Press Headquarters on the Mezzanine of the Statler. Excellent coverage by the daily trade papers and by the New York daily newspapers was responsible for a large share of the increase in the registrations.

"Session will open with a motion picture short"

THUS READ the beginning of each session's description in the 69th Semiannual Convention program. Emerson Yorke, Chairman of the Convention Committee on Motion Pictures, screened 40 films to choose a dozen fine 16- and 35-mm one-reelers. Those attending the Convention were enthusiastic about not only the high quality and cogent subject matter, but also the pertinence of the films as Emerson Yorke arranged them for each session. The films were:

*The Screen Director**	35-mm b & w	Warner Bros.
*The Cinematographer**	35-mm b & w	Paramount
A General Returns	16-mm b & w	NBC-TV News Special Events
*Movies Are Adventure**	35-mm b & w	Universal-International
*History Brought to Life**	35-mm b & w	Paramount
High-Speed Photographic Studies of Welding Arcs	16-mm color	U.S. Navy Bureau of Ships
Glory of Spring	16-mm color	Ott Pictures
Grandad of Races (Academy "Oscar" Award)	35-mm color	Warner Bros.
The Navy in Science	35-mm b & w	U.S. Navy
*The Art Director**	35-mm b & w	20th Century-Fox
*Moments in Music**	35-mm b & w	MGM
*The Soundman**	35-mm b & w	Columbia

Titles marked with an asterisk are from a group of one-reelers, *The Movies and You!* (in several cases they are prereleases), which has been put together by the motion picture industry in cooperation with the Academy of Motion Picture Arts and Sciences, and is designed to present the story of the behind-the-scenes activities in the production of motion pictures. All of these films are available to 16-mm users from Teaching Film Custodians, Inc., Agent for Board of Trustees of *The Movies and You!*, Industry Short Subject Project, 25 W. 43d St., New York 18.

Courtesy Theater Admissions

Entertainment, in addition to the Cocktail Hour and the 69th Semiannual Banquet and Dance and the extensive Ladies' Program, was pleasantly enhanced by courtesy admissions extended by:

Capitol Theatre
Paramount Theatre
Radio City Music Hall
Roxy Theatre
Warner Strand Theatre

Board of Governors

One day before the Convention, Sunday, April 29, the Board of Governors met in New York to review administrative, technical, and publication operations of the Society for the first quarter of 1951.

Agreement was unanimous on the need for additional space for Society Headquarters and the Board endorsed the recommendation that 2000 square feet of available space at 40 West 40th Street be taken without delay. The move, which will take place in the first or second week of June, became necessary because after nearly a year of ineffective negotiating, there appeared to be little chance of securing adequate space in the building at 342 Madison.

It was also agreed that every possible effort should be made to induce many more engineers in both motion pictures and television to apply for membership in the Society. The present trend is in the right direction, but extra attention to this program on the part of all Society members is clearly called for.

Test films, and the need for constant vigilance to maintain their technical quality within the limits of published specifications, were discussed. The Board learned that the search for a qualified test film quality control engineer, previously authorized, had been successful and that Fred Whitney, long associated with the ERPI Division of the Western Electric Co. and Altec Service Corp., had joined the Headquarters staff to serve in that capacity.

Engineering Activities

Fifteen committee meetings were held during the week of the Convention. These were:

Theater Television
Laboratory Practice
Screen Brightness
High-Speed Photography
Television Film Equipment
16- and 8-Mm Motion Pictures
Films for Television
ASA Committee PH22
Film-Projection Practice
Magnetic Recording
High-Speed Photography Liaison of Societies
Optics
Test Film Quality
Film Dimensions
Theater Engineering

Times for the committee meetings were chosen to give a minimum of interference with the Papers Program. Since the program had been assembled several weeks before the Convention and technical papers had then been scheduled for presentation in related subject groups it was not difficult for Hank Kogel and the committee chairmen to steer clear of obvious conflicts. Several committees met prior to the session of most interest to their members so each chairman could give Society members a last-minute report on the current work of his group. In addition, chairmen of certain engineering committees were chosen by the Papers Committee as chairmen of related technical sessions. This was quite appropriate for several reasons: first, the chairman was familiar with the subject matter of papers on his session; second, he could introduce the session with any "oral version" of his Committee's latest report to establish the Society's official interest in the general subject of that session; and third, his knowledge of the subject let him stimulate discussion from the floor following each paper.

BOOK REVIEWS

Father of Radio:
The Autobiography of Lee de Forest
Published (1951) by Wilcox & Follett, 1255 South Wabash Ave., Chicago 5. 502 pp. Appendix and Index. Illus. Price $5.00.

Dipping his pen in a concentrated mixture of emotion and pride, Lee de Forest takes the reader across his years from childhood to today—rarely inhibited and often with a chip on his shoulder, resenting fate and contemporaries. There is no bashfulness in his title "Father of Radio," or in his array of numbered claims of "firsts," including: "1. World's first wireless transmission overland—1904. . . . 4. World's first broadcast—1907. . . . 5. World's first transmission of voices without wires. . . . 8. World's first successful telephone amplifier—1912. . . . 14. World's first theatrical presentation of sound-on-film talking motion picture—1923." The jacket proclamation tends to assert that the world would not have been the same without him and points to the "electron tube," meaning the Audion, declaring the debt of radio, phonograph, talking pictures, television, radar, the cyclotron, the guided missile," etc. "Even atomic bombs would be impossible without it."

Dr. de Forest's account of himself is extraordinarily subjective, even for an inventor's book about himself. The volume is curiously interlarded with the sweet dolor of his loves and marriages, and here and there bursts into poesy. You are liable to fall out of the laboratory into the moonlight as you turn a page and there is in addition an appendix, pages 469 to 476, entirely devoted to his odes and vesper songs.

Another appendix section presents extracts from his paper read before The Franklin Institute in 1920 to relate the evolution of the Audion, which is appropriate enough as bearing on Dr. de Forest's best known contribution. This reviewer thinks it could have been fuller.

Dr. de Forest traces the Audion's ancestry back to his quest for a detector for wireless signals. He explored their possible effects on heated gas from such sources as the incandescent mantle lamp and the Bunsen burner, to no avail. Then he came upon a notion about the incandescent filament electric lamp. In the paper, he lightly and swiftly passes over a possibly highly basic fact with: "I was familiar with the Edison effect and many of the investigations thereof carried on by scientists."

That "Edison effect" can do with a bit more attention. In the early years of the incandescent light, Edison sought to double the life of the fragile lamp by making it with a spare filament, which could be cut into circuit when the first burned out. He found that there was an unexpected electrical potential generated in the idle spare filament when the first was in service. In fact he set William Kennedy Laurie Dickson, he of mixed and unhappy later fame in motion picture matters, to work exploring the subject and filling a notebook with data. There was too much to explore and do in those fecund and often troubled days and the "Edison effect" went into the future file, where it was to repose.

That for the reference to the "Edison effect," in the appendix. Now turning forward into the narrative, page 213, says Dr. de Forest: "Repeated failure with our own crude instruments and skill finally induced me in 1905 to follow Babs' advice to lay the problem of constructing an incandescent lamp containing a carbon filament and a small platinum plate . . . in the lap of a manufacturer of miniature lamps . . ."

Now to identify this helpful "Babs" one turns farther forward to page 151 of the narrative and finds: "At this stage (1902–03) I hired a queer looking, hawk-nosed inventive individual endowed with an encyclopedic memory by the name of Clifford D. Babcock. He had a wide experience with various inventors, Edison among others . . ."

This adds up, not to any animadversion on the origin of the Audion, but to observe that organization of the facts could have been improved. Sometimes Dr. de Forest is more poet than scientist.
—Terry Ramsaye, New Canaan, Conn.

American Standard Abbreviations for Use on Drawings, Z32.13-1950

Published (1950) by the American Standards Association, 70 E. 45th St., New York 17. 32 pp. 8½ × 11 in. Paper bound. Price $1.00.

This newly revised edition has profited from the several years field experience of its predecessor which was published in 1946. As stated in the foreword to the 1950 edition, "primary consideration was first given to suggested changes and additions volunteered by users of the standard." The new standard contains well over 2000 abbreviations selected for use on drawings where space and drafting time are considerations. These abbreviations are not intended for use in text matter or equations.

The abbreviations listed are, on the whole, for specialized terms that would in many cases be known and understood only by specialists in each of the various technical fields covered. This standard, therefore, would be of considerable help to anyone required to read or prepare drawings in a field other than his specialty. Motion picture and television engineers, for example, would have little difficulty in recognizing abbreviations such as MC, TV or UHF. If they strayed into other technical fields, however, they would certainly require the assistance of the Standard for such as APCI or NP.

Abbreviations in the electronics and television fields are extensive, but those relating to the motion picture field are scant. PROJ, for example, stands for project or projectile but not projector or projection. No abbreviations are given for camera, motion picture or angstrom. Also in the realm of constructive criticism, the section of the standard entitled "A Partial List of Engineering Societies and Industrial Associations" would benefit by including the Society of Motion Picture and Television Engineers (SMPTE) and by showing the revised name of the Radio and Television Manufacturers Association (RTMA). The standard, however, is an ever-growing compilation and this edition should be recognized for the excellent coverage it has given to so many varied and complex fields.—CHARLES A. MEYER, Tube Department, Radio Corporation of America, Harrison, N.J.

The Use of Mobile Cinema and Radio Vans in Fundamental Education

Published (1949) by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Publication No. 582. Distribution agent in the U.S.A., Columbia University Press, 2960 Broadway, New York 27. 164 pp. 26 pp. photos and diagrams. 5¼ × 8½ in. Paper cover. Price $1.00.

Mobile projection trucks (or vans) have been used only to a slight extent in the United States, for there is hardly a town or community in the settled portions of this country that does not either own its own sound-on-film and slide projector or have access to one. There are, however, some districts—for instance in the Appalachian highlands, the far South and the desert areas of the western states—where complete projection facilities, including power supply and living quarters, might fill a need. This book is of special interest for those who may want to bring educational films to people to whom more permanent facilities are not available.

The Use of Mobile Cinema and Radio Vans in Fundamental Education was prepared for UNESCO by the Film Center in London. It describes traveling radio and motion picture exhibition units and outlines the history and use of such units in Great Britain and the colonies, Canada, Russia and other countries. In these places the mobile units are under the education, public health or information departments of the governments.

Complete data are given for the building and furnishing of a truck with 16-mm motion picture, slide film, radio receiving and public address equipment. Included are details of such features as shock mounting, tropical treatment, stowage and living quarters for the crew.

One interesting application was the rebuilding of an army "duck," complete with power and living quarters, in order to show educational motion pictures to residents on the rivers in India.

There is a wealth of information in the appendixes. References, bibliography, equipment specifications, training courses, diagrams and excellent photographs complete the book.—WILLIAM K. AUGHENBAUGH, Radio Station WLW-T, The Crosley Broadcasting Corp., Cincinnati.

Proceedings of the Speech Communication Conference at M.I.T.

These *Proceedings* were published as a unit of 116 pp. which is part of the *Journal of the Acoustical Society of America,* vol. 22, no. 6, Nov. 1950. The following twenty-four papers were presented at this conference held May 31–June 3, 1950, at Massachusetts Institute of Technology, under the joint auspices of the Acoustical Society of America, the Carnegie Project on Scientific Aids to Learning at M.I.T., and the Psycho-Acoustic Laboratory at Harvard University:

Introduction: A Definition of Communication, S. S. Stevens, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

The Information Theory Point of View in Speech Communication, R. M. Fano, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Speech, Language, and Learning, Norbert Wiener, M.I.T., Cambridge, Mass.

Typology of Languages, Paul Menzerath, Phonetic Institute, Bonn University, Germany

Description of Language Design, Martin Joos, University of Wisconsin, Madison, Wisconsin

The Relation of Phonetics and Linguistics to Communication Theory, Oliver H. Straus, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Speech and Language, John Lotz, Columbia University, New York, N.Y.

Pathology in Speech Communication, Ira J. Hirsh, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Language Engineering, George A. Miller, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Communication Patterns in Task-Oriented Groups, Alex Bavelas, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

Sonograph and Sound Mechanics, Jean Dreyfus-Graf, Geneva, Switzerland

The Calculation of Vowel Resonances, and an Electrical Vocal Tract, H. K. Dunn, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

An Apparatus for Speech Compression and Expansion and for Replaying Visible Speech Records, F. Vilbig, Air Force Cambridge Research Laboratories, Cambridge, Mass.

Spectrum Analysis, Franklin S. Cooper, Haskins Laboratories, New York, N.Y.

Correlation Function Analysis, L. G. Kraft, Research Laboratory of Electronics, M.I.T., Cambridge, Mass.

System-Function Analysis of Speech Sounds, W. H. Huggins, Air Force Cambridge Research Laboratories, Cambridge, Mass.

Portrayal of Some Elementary Statistics of Speech Sounds, S. H. Chang, Electronic Research Project, Northeastern University, Boston, Mass.

Autocorrelation Analysis of Speech Sounds, K. N. Stevens, M.I.T., Cambridge, Mass.

Theory of Operation of the Cochlea: A Contribution to the Hydrodynamics of the Cochlea, O. F. Ranke, Physiologisches Institut, University of Erlangen, Germany, U.S. Zone

Theory of the Acoustical Action of the Cochlea, J. Zwislocki, University Clinic for Ear, Nose and Throat, Basel, Switzerland

Neurophysiology of the Auditory System, Robert Galambos, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Auditory Masking and Fatigue, Walter A. Rosenblith, Psycho-Acoustic Laboratory, Harvard University, Cambridge, Mass.

Binaural Localization and Masking, W. E. Kock, Bell Telephone Laboratories, Inc., Murray Hill, N.J.

Reversed Speech and Repetition Systems as Means of Phonetic Research, W. Meyer-Eppler, Phonetisches Institut der Universität, Bonn, Germany

Single copies of this *Journal* are available at $2.00 each from the American Institute of Physics, 57 E. 55th St., New York 22.

Dictionary of Color
New Second Edition

By A. Maerz and M. R. Paul. Published (1950) by McGraw-Hill, 330 W. 42d St., New York 18. 208 pp. 8¾ × 11¾ in. Price, $25.00.

From inspection of the sample sheet sent out with literature advertising the second edition of this standard color names dictionary, it would seem that the job of reproducing the first edition has been a good one. Over seven thousand samples appear in the book, with color names keyed to samples matching (for the first edition) a wide series of color names taken from several sources to represent standard usage in many fields. In the second edition many names have been added, including those for the 9th edition of the *Standard Color Card* of the Textile Color Card Association of the United States, and those sponsored by *House and Garden*. Because newly developed pigments were used in this edition with a resulting "improvement of depth, purity, and brilliance of many of the colors, with small shifting of match in some cases" it is advised by the publishers that the edition of the book be stated when exact match or reference is desired. Eight groups of hue ranges are shown in plates of 144 or 72 blocks to a page, each group consisting of several pages which extend from the purest colors, through successive pages for darker, grayer colors until they reach near-blacks. The Maerz & Paul dictionary provides a large assortment of color samples at a very reasonable price. It has proved a standard reference work for color names since its original publication in 1930. The second edition should continue to fill the need for this type of color reference work.—Dorothy Nickerson, Cotton Branch, PMA, United States Department of Agriculture, Washington 25, D.C.

Descriptive Color Names Dictionary

Edited by Helen D. Taylor, Lucille Knoche and Walter C. Granville. Published (1950) by Container Corporation of America, 122 E. 42d St., New York 17. 60 pp. Price $2.00.

This 60-page dictionary of color names used in mass-market merchandising, such as in the mail-order field, describes current work in the color names field. Both Mrs. Taylor and Miss Knoche have been collecting information and keying color names to materials actually used by large mail-order houses such as Sears Roebuck and Montgomery Ward, for many years. In this dictionary they have keyed the names to samples in the third edition of the *Color Harmony Manual*, published last year by the Container Corporation. While the book is intended as a supplement to the *Color Harmony Manual*, nevertheless it should be useful for general color names work, particularly when ICI and Munsell specifications are published for the samples of the *Manual*. Because the work has been done by persons so close to mass-market merchandising use, it should carry considerable authority. Publication of colorimetric data on the samples to which the names are keyed is promised by Mr. Granville for the near future. While some of the names overlap, so that several names may apply to the same sample, for other samples in the *Manual* no mass-market names are in use. The publication should be very useful to all interested in color names; it is a must for those who own the *Manual*.—Dorothy Nickerson, Cotton Branch, PMA, United States Department of Agriculture, Washington 25, D.C.

Journals Out of Stock: The Society's stock of Journal issues for March, Part II, July, August, September, 1949, and February, 1950, has been exhausted as a result of an unexpected increase in demand and the Society's Headquarters is anxious to purchase a stock of each. Members or libraries having extra copies available are invited to send them in. The going price is 75c.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April Journal.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Anderson, Vernon E., Photographer and Laboratory Technician, Society for Visual Education, Inc. **Mail:** 2955 N. Nordica Ave., Chicago 34, Ill. (A)

Armstrong, A. Millard, Attorney, 529 Fairwood Ave., Columbus 5, Ohio. (A)

Aulabaugh, Sarah Jane, Research Photographer, Monsanto Chemical Co. **Mail:** 436 Red Haw Rd., Dayton 5, Ohio. (M)

Behrend, William L., Research Engineer, RCA Laboratories. **Mail:** 357 Nassau St., Princeton, N.J. (M)

Bunting, Eugene N., Bay State Film Productions, Inc. **Mail:** 65 Lee St., East Longmeadow, Mass. (M)

Burleson, John E., Information and Education Specialist, Navy Department. **Mail:** 3356 Martha Custis Dr., Alexandria, Va. (A)

Burrell, John E., Television Engineering Supervisor, National Broadcasting Co. **Mail:** 11602 Hartsook St., North Hollywood, Calif. (A)

Castle, Clemens X., Chief Engineer, WJIM-TV. **Mail:** 315 W. Brown St., Birmingham, Mich. (M)

Chaney, Harold Lee, University of Southern California. **Mail:** 660 W. Jefferson Blvd., Los Angeles 7, Calif. (S)

Cherry, Herbert, Stage Electrician, Park Theatre. **Mail:** 1916 N. Stanley St., Philadelphia 21, Pa. (A)

Chesley, Albert Bernard, Washington University. **Mail:** 216 S. Fifth St., Fort Dodge, Iowa. (S)

Cunliffe, Donald C., Sound Recorder, Universal-International Pictures Co. **Mail:** 4356 Lemp Ave., North Hollywood, Calif. (A)

Eckhard, Henry W., Television Projectionist, KPIX. **Mail:** 71 Liebig St., San Francisco Calif. (A)

Fagerstrom, William H., Motion Picture Operator, F.W.C. Theaters. **Mail:** 719 Westbourne Dr., Los Angeles 46, Calif. (A)

Franco, Maurice, Electronic Project Engineer, Houston Corp. **Mail:** 527 N. Mott St., Los Angeles 33, Calif. (A)

Gisbrecht, James H., Electrical Engineer, Northrop Aircraft. **Mail:** 10323 Mansel Ave., Inglewood, Calif. (A)

Goris, Edward N., Sales Engineer, General Electric Co. **Mail:** 212 N. Vignes St., Los Angeles, Calif. (A)

Gray, John B., Senior Electrical Engineer, Diebold, Inc. **Mail:** 13 Senga Rd., South Norwalk, Conn. (M)

Harmon, Ralph N., Engineering Manager, Westinghouse Radio Stations, Inc. **Mail:** 1625 K St., N.W., Washington, D.C. (M)

Hayes, Roy O., Chief Projectionist, Columbia Amusement Co. **Mail:** 713 Kentucky Ave., P.O. Box 123, Paducah, Ky. (A)

Hillie, Edward M., Television Director, KNBH, National Broadcasting Co., Inc., Sunset and Vine, Hollywood 28, Calif. (A)

Hobby, Fred, Film Technician, Guffanti Film Laboratories, Inc. **Mail:** 2007 Newbold Ave., New York 61, N.Y. (A)

Hoffman, Donald D., Motion Picture Cameraman, The Calvin Co. **Mail:** 3130 Euclid, Kansas City, Mo. (A)

Holland, Sheldon C., Manager, Photographic Dept., Bell Aircraft Corp. **Mail:** 78 Briggs Ave., Buffalo 7, N.Y. (A)

Hotchkiss, Calvin M., Photographic Engineer, Motion Picture Division, Eastman Kodak Co., 342 Madison Ave., Suite 626, New York 17, N.Y. (M)

Hunt, Thomas E., Partner, Colortran Converter Co. **Mail:** 7045 Romaine, Hollywood 38, Calif. (M)

Jewell, Raymond W., University of Southern California. **Mail:** 837 W. 36 Pl., Los Angeles 7, Calif. (S)

Knight-Simpson, Beric W., Cinema Officer, Nigerian Government. **Mail:** Public Relations Dept., 11 Custom St., Lagos, Nigeria, West Africa. (A)

Kugel, Gerhard W., Audio Recording Technician, Dallas Jones Productions. **Mail:** 1725 N. Wells St., Chicago, Ill. (A)

Latil, J. P., President, Genarco, Inc. **Mail:** 116-46—82 Dr., Kew Gardens, N.Y. (M)

Ledoux, Robert F., Chief, Photographic Laboratory, Springfield Armory. **Mail:** 102 Draper St., Springfield, Mass. (A)

Levene, Sanford M., New York University. **Mail:** 62-65 Saunders St., Rego Park, N.Y. (S)

Lewis, Joseph R., Vitapix Engineer, American Broadcasting Co. **Mail:** 629 Casanova St., Bronx 59, N.Y. (A)

Luckey, Richard S., University of Southern California. **Mail:** 942 W. 34 St., Los Angeles 7, Calif. (S)

Moltz, Jerome Winslow, II, University of Southern California. **Mail:** 6452 W. 85 Pl., Los Angeles 45, Calif. (S)

Moran, Austin G., Chief Engineer, Dominion Broadcasting Co. **Mail:** 6 Baby Point Ter., Toronto, Canada. **(A)**

Moyer, Eldon, Motion Picture Work, Eastman Kodak Co. **Mail:** 31 Holcroft Rd., Rochester, N.Y. **(M)**

Muchmore, John, Sound Maintenance Engineer, Universal Pictures Co. **Mail:** 10724 Aqua Vista St., North Hollywood, Calif. **(A)**

Nicholas, Guy E., Photographer, State Highway Commission, State of Maine. **Mail:** 101 N. Main St., Rockland, Me. **(A)**

Orrell, Percy, Agent, Ampro Corp. **Mail:** 34 Mendon St., Hopedale, Mass. **(A)**

Plumb, Edward W., Film Director, The Standard Oil Co. (Ohio). **Mail:** 3167 W. 92 St., Cleveland 2, Ohio **(A)**

Preo, Paul H., Development Engineer, Eastman Kodak Co. **Mail:** 331 Conrad Dr., Rochester 16, N.Y. **(A)**

Pugliese, Guy, Photographer, Commonwealth of Pennsylvania. **Mail:** 2635 Jefferson St., Harrisburg, Pa. **(A)**

Rengel, Richard E., University of Southern California. **Mail:** 7953 Ranchito Ave., Van Nuys, Calif. **(S)**

Reynolds, Floyd L., Test Engineer, Universal-International Pictures Co. **Mail:** 4514 Farmdale, North Hollywood, Calif. **(A)**

Ries, Irving G., Special Photographic Effects, Metro-Goldwyn-Mayer. **Mail:** 17501 Castellammare Dr., Pacific Palisades, Calif. **(M)**

Ruskin, Phil, TV Remote Director, WBKB. **Mail:** 5717 N. Christiana, Chicago 45, Ill. **(A)**

Rzewinski, Leonard, Engineer, Meridian Instrument Corp. **Mail:** 261 Montauk Ave., Brooklyn 8, N.Y. **(A)**

Seat, E. Toral, Director of Bureau of Visual Education, World-Wide Bible Pictures, Pacific Union Conference. **Mail:** 709 Glenmore Blvd., Glendale 6, Calif. **(M)**

Shekell, Lennox, University of Southern California. **Mail:** 1039 W. 31 St., Los Angeles 7, Calif. **(S)**

Simmons, James W., Photographer, 4124 Park, Kansas City, Mo. **(A)**

Stevens, M. H., Manager, Industrial Sales Division, Bausch & Lomb Optical Co. **Mail:** 20 Alexander St., Rochester 20, N.Y. **(M)**

Valentine, Fred, Heald Engineering College. **Mail:** P. O. Box 4687, San Francisco, Calif. **(S)**

Vaughan, William Kent, Engineer, Carthage Machine Co. **Mail:** 226 N. School St., Carthage, N.Y. **(A)**

Weiser, Sidney, Mechanical Engineer, Federal Manufacturing and Engineering Corp. **Mail:** 255–43 75 Ave., Floral Park, L.I., N.Y. **(M)**

White, George C., Jr., Physicist, Frankford Arsenal. **Mail:** 3515 N. 22 St., Philadelphia 40, Pa. **(M)**

Wilson, Carlton F., Producer-Director, Imperial Oil, Ltd. **Mail:** 365 Bayview Ave., Apt. #6, Toronto, Ontario, Canada. **(M)**

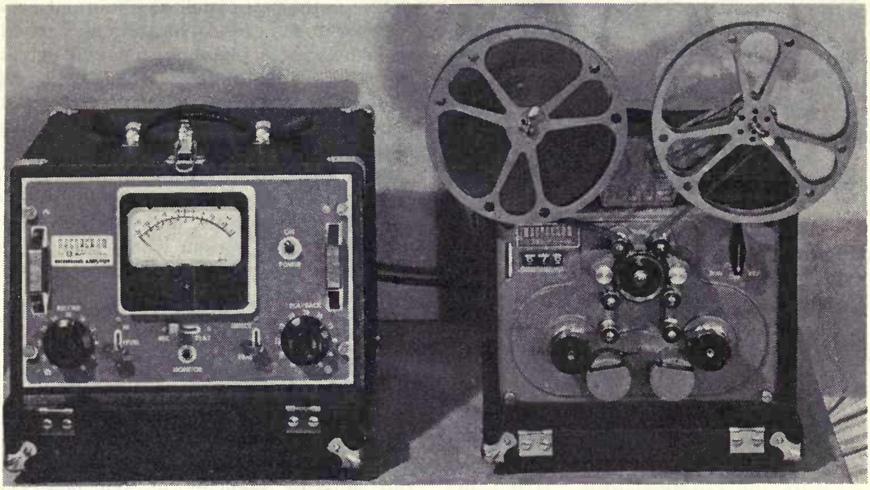
Personals

Dr. Adolph H. Rosenthal, formerly Director of Physics for the Freed Radio Corp., New York, has been appointed Vice-President and Director of Research and Development. Prior to his association with Freed Radio, Dr. Rosenthal was engaged for many years in electronic research for American and British concerns. Best known among his 30-odd patents is the Skiatron or "dark-trace" cathode-ray tube which has had a wide application in television, motion pictures and military electronics. At one time, Dr. Rosenthal was engaged in research at the Einstein Institute in Potsdam, applying television methods to solar observations. He will supervise government development projects for which Freed has built enlarged laboratory facilities.

Louis Gerard Pacent, a Fellow of the SMPTE, has been awarded the Marconi Memorial Medal of Achievement for his pioneer work in radio and communication by the Veteran Wireless Operators Association. At the beginning of Mr. Pacent's career, he worked very closely with Marconi himself. Mr. Pacent was a pioneer in the manufacture of theater motion picture sound reproducing equipment, and his many installations in 1929 and 1930 gave impetus to the infant talking picture and made it possible for exhibitors to take advantage of the new art. He is now president of the Pacent Engineering Corp., New York. His many contributions to the war effort during World War II brought citations to his company.

New Products

Further information about these items can be obtained directly from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

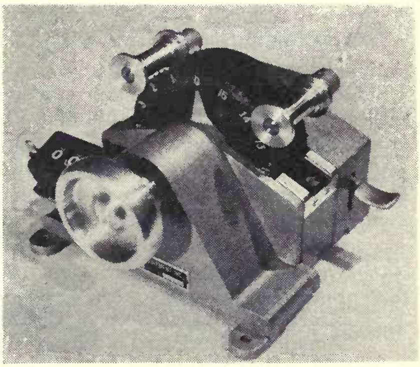


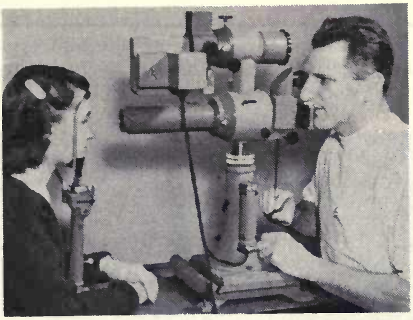
A magnetic film recorder that weighs only 38 lb distributed over two cases, the mechanical-drive case being 11 × 9 × 8 in. and the amplifier case being 12 × 8½ × 8 in., is being marketed by the Magnagram Corp., 11338 Burbank Blvd., P.O. Box 707, North Hollywood, Calif. Known as F-102 Field Unit Sub Miniature Magnetic Film Recorder, it incorporates the Magnagram "Synkinetic" dual-inertia wheel drive with flutter under 3%.

Frequency response is 50 to 10,000 cps within 2 db at 90 ft per min. Film capacity is from 400 to 1200 ft (up to 33 min of recording). Amplifier terminals provide for low-impedence mike and 600-ohm zero-level inputs and 600-ohm zero-level output. There is a 4-in. illuminated V.U. meter, direct, and "off-the-film" monitor. A large, easy-to-read footage counter is interlocked with drive shaft to operate forward and in reverse. The recorder is designed to operate vertically or horizontally. The universal motor drive is readily adaptable to operation with selsyn and other interlock motors. 16-Mm or 17½-mm film drive is optional.

A high-quality instrument for the synchronization and measurement of 16-mm and 35-mm films, known as the Syncrometer, is being produced by National Cine Equipment, Inc., 20 W. 22d St., New York 10. The Syncrometer provides finger-tip roller release and positive roller contact, and prevents film sprocket jump at any rewind speed.

Any combination of 16-mm and 35-mm sprocket assemblies can be made by the manufacturer. The Syncrometer is of the foot-linear type, graduated for 40 frame divisions on the 16-mm sprocket and 16 frame divisions on the 35-mm sprocket. Film stripper shoes prevent film creep under sprockets.





A high-speed still camera for photographing the retina, nerve fibers and other structural elements of microscopic size in the interior of the eye is now being produced by Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N.Y.

Bausch & Lomb developed the camera at the request of the U.S. Public Health Service for studies showing the relationship between enlarged retinal blood vessels and such vascular diseases as high blood pressure and arteriosclerosis. It is being used extensively in the "rice diet" research and treatment of these diseases. Photographs of the interior of the eye are taken periodically and superimposed so that the diameter and tortuosity of blood vessels may be compared at various stages of treatment.

Eye pathologies such as abnormal condition of blood vessels, location and extent of hemorrhages, pigmentation, and extent of cupping of the nerve head may be studied with the new camera. The last condition is of importance in diagnosing and treating glaucoma, and the photographs may aid in detecting, in addition to those mentioned, such systemic diseases as diabetes, nephritis, and tumors of the central nervous system where changes in the retina occur long before the appearance of clinical symptoms.

Series photographs of these conditions may be used to chart their progress and as a visual aid for teaching medical and optometric students. Photographs may be enlarged many times or projected onto a screen for scrutiny by surgeons before and after operations. Photographs of the anterior segment of the eye—the lids, iris, cornea, sclera, etc.—may also be taken with the camera.

Meetings of Other Societies

American Physical Society, June 14–16, Schenectady, N.Y.

American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Illuminating Engineering Society, Aug. 27–30, Washington, D.C.

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

Acoustical Society of America, Oct. 23–25
Optical Society of America, Oct. 23–25
Society of Rheology, Oct. 24–26
American Physical Society, Oct 25–27
American Association of Physics Teachers, Oct. 25–27

Three-Dimensional Motion Picture Applications

By R. V. Bernier

Images on the retinae of the eyes, resulting when viewing real life subject matter, are not in themselves three-dimensional. The impulses from these images which travel to the brain supply the brain with the data it needs to build the three-dimensional vision which the observer sees in lieu of the subject itself. Present grainless motion picture color film is a nearly perfect medium of establishing synthetic images on the retinae which equal the natural ones. As a result, the data that reaches the brain is comparable to that which might emanate from natural images. The brain, detecting little difference, forms a synthetic vision nearly as perfect as natural vision.

The three-dimensional motion picture camera has been employed with success to capture all of the components of depth perception which are associated with natural vision. In addition high-speed and time-lapse applications have been developed which also incorporate factors of depth perception otherwise impossible to duplicate in natural vision.

A solution of the flicker problem in 16-mm, alternate-frame, stereo projection at 24 frames/sec has been provided through the use of the Morgana shuttle movement. Also the requirement for registration adjustments before or during projection has been eliminated by the use of a barrel-type polarizer which permits projecting through a single-lens axis.

THE TREND indicates that eventually methods for imaging, transmitting or preserving and re-presenting subject matter will approach a state of perfection. This state of perfection will provide a synthetic vision of the subject which will be difficult to detect from reality. Three-dimensional motion pictures are a step in this direction, as is also three-dimensional television, although it is still more experimental.

Much has been accomplished on three-dimensional taking and projecting equipment and on the general problems involved. Noteworthy is the work of H. E. Ives,[1] who pioneered the composite or lenticulated system, E. H. Land,[2] who invented Polaroid and thus simplified the problem of projection, and J. A. Norling.[3] The first commercial application of Polaroid to a three-dimensional picture is credited to Norling who produced and exhibited a 35-mm black-and-white motion picture

Presented on May 2, 1951, at the Society's Convention at New York, by Maj. R. V. Bernier, U.S.A.F., Stereo and Photomicrographic Unit, Instrumentation and Analysis Section, AMC Photo Service Center, Wright-Patterson Air Force Base, Dayton, Ohio.

at the New York Worlds Fair in 1939. Previous three-dimensional pictures requiring red and green viewing devices and subsequent three-dimensional films produced by Norling have made him in the author's opinion a well qualified authority on the subject. In his papers which he presented at the fall meeting of the SMPE at New York in 1939, and at the spring meeting at Rochester in 1941, he discussed thoroughly this subject of three-dimensional motion pictures. In view of this and other published literature on the subject this paper will be confined to a brief discussion of the synthesis of vision, followed by a discussion of the equipment and principles involved.

Synthetic Vision

Both motion pictures and television are excellent mediums for portraying subject matter in a real and lifelike manner. Their three-dimensional possibilities cannot be fully appreciated until the synthesis of natural vision is examined and understood.

When we look at a subject or scene, rays of light therefrom enter the displaced pupils of each of our two eyes and form real images on the retinae. It is true that these images are slightly different because they were formed from different viewpoints, and it is also true that this difference is an extremely important factor. Even though this fact is considered, these images are not so unusual. It is the three-dimensional vision formed by the brain which is really unusual and really miraculous. The brain forms this remarkable vision by compiling the millions of electrochemical impulses being generated at the retinae and arriving through the medium of the optic nerves. This fact indicates that if the natural retinal images could be exactly duplicated synthetically there would be no change in the character of the impulses being generated. Thus, the brain would form the same remarkable three-dimensional vision. It is evident from the foregoing that in natural vision we do not see the actual subject itself, we see a vision of it as set up by the brain.

To create synthetic vision, which could be, and eventually will be almost as remarkable as natural vision, we need to deal only with the retinal images. The impulses and resultant true three-dimensional vision will occur automatically once we have supplied faultless images. The natural retinal images were described above as not unusual, the implication being that they are not in themselves three-dimensional. Other than lying in a spherical plane they are quite analogous to a good photographic lens image. This suggests that they could be duplicated in the focal plane of a twin-lens camera. The problem rests simply in transporting them from these focal planes to the retinae, intact, that is to say, without loss of resolution, color quality, etc. When this is accomplished and faultless synthetic images are supplied to the retinae, it will, for example, be quite possible to stand in the middle of the Mojave Desert and actually feel that we are physically at Palm Springs. This sensation of realness is nearly natural today, especially when high-quality motion picture films and the correct viewing conditions are employed as the medium of transporting the images from the twin-lens camera focal plane to the retinae.

Further improvements in the naturalness of synthetic vision depend for the most part on improvements in the transporting medium whether it be motion picture films, television, or both, these being the only mediums to date which can adequately capture all of the factors of depth perception.

Factors of Depth Perception

All factors of depth perception must be present if we wish synthetic vision to equal natural vision. These factors are:

1. Light and shadow
2. Perspective
3. Color
4. Focus reaction
5. Movement of the viewpoint
6. Stereoscopic vision

Only the first two of these factors are incorporated in a black-and-white paper print, and only the first three are present in a color transparency.

The fourth factor, focus reaction, needs some explanation. It is the reaction which assists us in estimating the relative positions, in space, of near objects. The physical change required of the eye lens to bring objects at different distances into sharp focus helps to advise us as to their actual distances from our viewpoint. This function of the human eyes is noticeably active only for objects closer than 6 or 7 ft. There is a decreasing degree of activity beyond this distance up to a maximum of 20 ft (optical infinity), but the reaction is so slight that it can be considered negligible.

The process of projection, or the process of viewing a print or transparency through a lens, in effect incorporates the focus reaction factor. That is partly the reason why these processes can cause subject matter to appear more lifelike. Actually in this case focus reaction is not activated. On the other hand, the fact that the flat plane of the image is projected beyond a point where focus reaction might be activated precludes, by the absence of the reaction, the opportunity to detect the lack of plasticity. In other words, the focus-reaction factor cannot assist in detecting that the screen image is flat unless the latter lies less than 6 or 7 ft from our viewpoint.

Two factors of depth perception do remain, however, and they can be employed by the observer to detect the presence or absence of solidity in a projected image.

The first of these, and a very important factor, is "movement of the viewpoint." When we are looking at a physical scene and choose to move our viewpoint laterally, subject matter in the foreground will appear to move further and will pass in front of the subject matter in the background. This phenomenon would not occur of course if we were looking at a single projected transparency and chose to move our viewpoint. The absence of this effect in this case would also betray the lack of solidity in the projected image.

The last factor, stereoscopic vision, surveys by triangulation the exact position of objects in respect to the eye base or viewpoint. This feature would also betray that all objects, being portrayed by the single image on the screen, were flat and were located in the plane of the screen. This is true, providing of course that the projection distance is not beyond the limit of our ability to triangulate, a distance generally conceded to be about one fourth of a mile. An interesting condition exists with the single lens pocket viewer. In this case the flatness of the image cannot possibly be detected, either by focus reaction since the image appears at infinity, or by stereoscopic triangulation since the second "station" needed to triangulate objects is precluded from use.

The Superior Medium

A full-color three-dimensional motion picture is superior to any other existing medium of synthetic vision. It is most capable of transporting the real moving images from the focal plane of the twin-lens camera to the retinae of the human eyes. The movement phenomenon previously discussed, which we unconsciously but always associate with natural vision when we ourselves move, can easily be incorporated by rotating the subject in front of the camera, or by moving the camera on a dolly or

boom toward, around, and/or over the subject.

Present grainless color film available to the industry can and does capture the stereo focal-plane images nearly unimpaired. Very little of the original aerial image quality is lost. In addition motion picture color film is capable of recording and transmitting to the retinae all factors of depth perception inherent in the original stereo focal-plane images.

Television Application

Considering the rapid progress being made in television, it also may soon provide a medium of synthetic vision comparable to natural vision. Curiously enough the mechanics of obtaining ortho-stereoscopic results in television are relatively simple. For example, the receiving end could consist of a small rectangular picture tube receiving the two required views side by side. The over-all dimensions of the tube face should be approximately 6 × 13 cm. For ortho-stereoscopic viewing this miniature tube should be encased in a small hand-held stereoscope-like viewer. This viewer would be equipped with twin 80-mm focal length, 35-mm diameter plano convex lenses, a "window" mask format, and a cable to connect it to a master receiver. The taking camera could be equipped with either twin lenses or a beam splitter attachment. In either case the stereo pair of images would be picked up side by side on the camera tube and transmitted in the usual manner.

ALTERNATE-FRAME TECHNIQUE

Obviously 35-mm motion picture film is superior to 16-mm in ultimate screen quality. Also it is evident that the success of future entertainment three-dimensional films, if and when they make their debut, is dependent not only on the appeal that this added feature might have, but also dependent on the quality of the screen image. Therefore present quality standards will have to be maintained or even improved upon.

To be sure, there are applications of the three-dimensional motion picture other than for entertainment purposes. These are principally in the fields of education, industry and science. In those fields portability of equipment and low production cost are prerequisites to the use of such films, and so 16-mm film seems to be the right answer.

The question is which of the known systems of 16-mm three-dimensional motion pictures is going to fulfill the rather strict requirements.

The author realizes that each system has its advantages and disadvantages, and that eventually one of these systems may prove superior to the others. In view of this, work is in progress now in connection with the development of a "split-frame" technique. The purpose is to compare all phases of its operation and results with the alternate-frame technique. Because the film presented with this paper was of the alternate-frame type and because of limitations placed on this paper, the following discussion will be confined to this system exclusively.

The original decision to concentrate effort on improvements in the alternate-frame technique was based on the possible advantages which could be had by maintaining full-frame standards and at the same time confining at least the projection to a single standard film. Figure 1 shows a sample strip of alternate-frame stereo film. On projection the right eye will see every alternate frame, the left eye will see those in between. Note the difference in position of objects on adjacent frames with respect to each other and to the edge of the film.

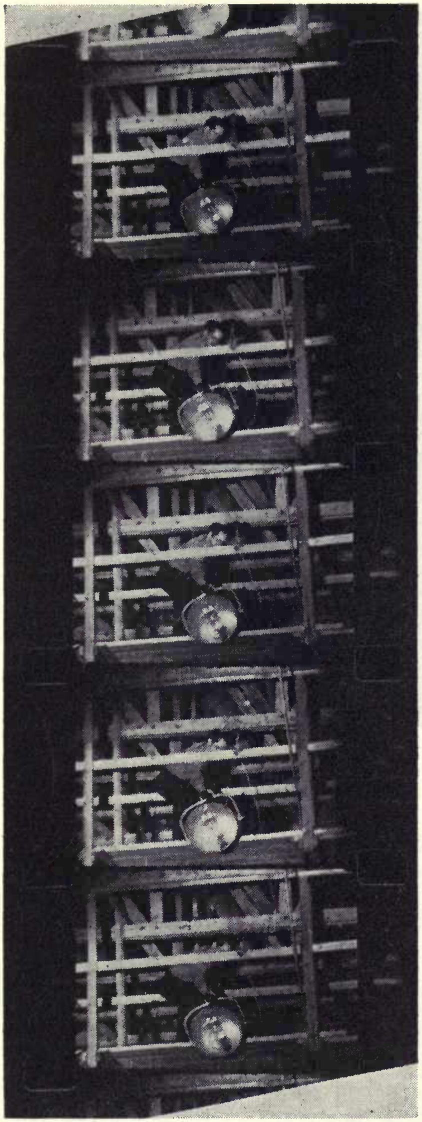


Fig. 1. Section of 16-mm alternate-frame stereo film.

Projection

The projection requirements for alternate-frame film are substantially the same as they are for stereo film of other systems. The right- and left-eye images must be registered properly on the screen and must be selectively polarized for their respective eyes. It has been the practice to use the same type of attachment on the projector that was used on the camera. Such an attachment, a beam splitter with synchronized shutter was tested prior to the development of the present adapter. The latter was developed in an attempt to eliminate the screen registration problems characteristic of the beam splitter attachment. Figures 2a and 2b show the principle of its operation. Figure 2a shows the Polaroid filter 16 which is semicylindrical and positioned to be rotated on its axis in the same plane as, but normal to, the lens axis. Polarization 20 of the filter when viewed from the lens position is 45° upward and to the left. A frame 22 having a left stereoscopic image therein is centered on the lens axis. The image 24 on the screen 18 may be seen with the left eye only by a viewer wearing standard Polaroid spectacles. In Fig. 2b, the film 12 has been advanced so that a frame 26 having a right stereoscopic image thereon is centered on the lens axis while the filter 16 has been revolved 180° from the position it occupied in Fig. 2a. It may be noted in Fig. 2a that the outside of the semicylindrical filter 16 is presented to the lens 14, while in Fig. 2b the inside of

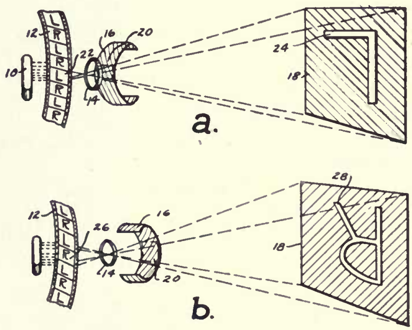


Fig. 2. Barrel polarizer principle of alternately and selectively polarizing right and left screen images.

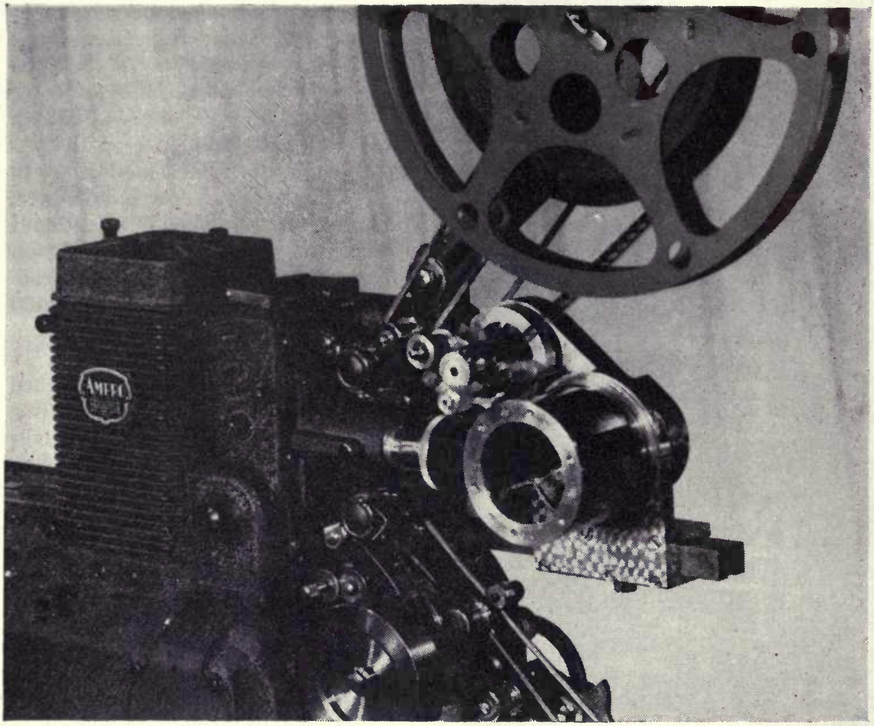


Fig. 3. Film-driven barrel polarizer attachment.

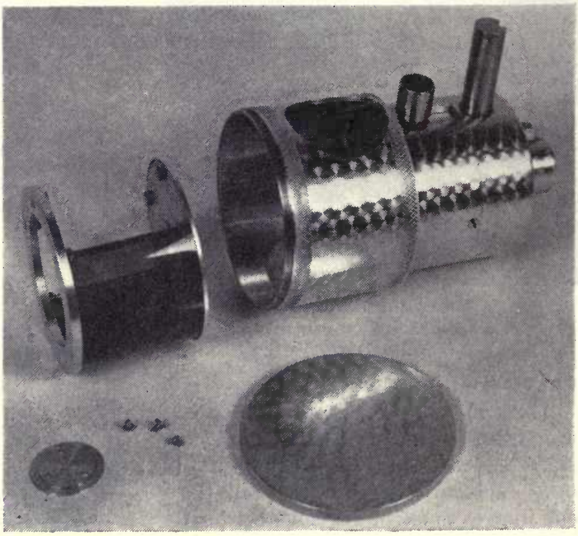


Fig. 4. Direct-drive polarizer attachment showing barrel and mounted Polaroid filter.

the semicylindrical filter is presented to the lens 14. Moreover, the same axis 20 of polarization which, in Fig. 2a, extended upwardly and to the left, now extends upwardly and to the right. Thus the image 28 on the screen 18 may be seen with the right eye only by a viewer wearing standard Polaroid spectacles.

Three stages of evolution of the barrel-type polarizer attachment[4] were: (1) a barrel driven through a gear train by power transmitted by the film itself (see Fig. 3); (2) the same attachment geared to operate at three times its original speed so that it could be used on a projector incorporating the Morgana[5] shuttle movement; and (3) an entirely new gear housing driving the same type of barrel polarizer through a direct power shaft on the projector (see Fig. 4).

Referring to Fig. 3 again, it will be noted that the film is threaded through a sprocket drive on the attachment. The latter has no other power connections to the projector. This attachment was first designed so that it could be used on almost any 16-mm projector. The movement of the film through the sprocket drive was sufficient to keep the polarizer in synchronization with its movement through the film gate. An adjustment knob on the attachment provided for changing the position of the drive sprocket with respect to the power sprocket on the projector. The increase or decrease in distance, by one frame length, between the two sprockets, served to synchronize the rotating polarizer with right or left frames, at will, during projection. This was necessary to compensate for discrepancies in the right–left–right, etc., sequence in the film due to threading or splicing errors.

As predicted, the flicker at 24 frames/sec was considerable. Increasing the speed of projection to 36 frames/sec helped somewhat but it was soon realized that some other approach to the problem would be necessary. The Morgana[5] shuttle movement proved to be the solution to the flicker problem. The Morgana movement was designed to eliminate the same sort of flicker in the two-color process. A search uncovered the existence of one of these mechanisms at the Bell & Howell plant in Chicago. It was procured and mounted on a Bell & Howell Showmaster chassis. The first polarizer attachment (Fig. 3) was then regeared to revolve at three times its former speed so as to correspond to the new framing speed of the Morgana movement. Previously while one eye was getting the benefit of three "flicks" the other had to wait through a period of $^1/_{24}$ sec. Now with the Morgana movement the fluctuation of light, with respect to either eye, was uniform. The system which involves shuttling one frame backwards for every two forward, facilitates progression of the film through the projector at standard sound speed, and at the same time provides a flicker frequency of 72 frames/sec, or 36 frames/sec per eye.

Figure 5 shows the final product in the evolution of the barrel polarizer. Here it is shown attached to the Bell & Howell Showmaster projector which in turn is equipped with a Morgana movement. The polarizer in this case is powered through its gear train directly by the gear mechanism of the projector and not by the film. This change was found to be necessary due to the inability of the film-driven model to stay in exact synchronization at the higher speed required with the Morgana movement.

Characteristics of the Alternate-Frame Principle

The alternate-frame principle offers certain advantages over the split-image system. Both the right-eye image and the left-eye image occupy standard full frames on the film. This feature provides for maintaining the

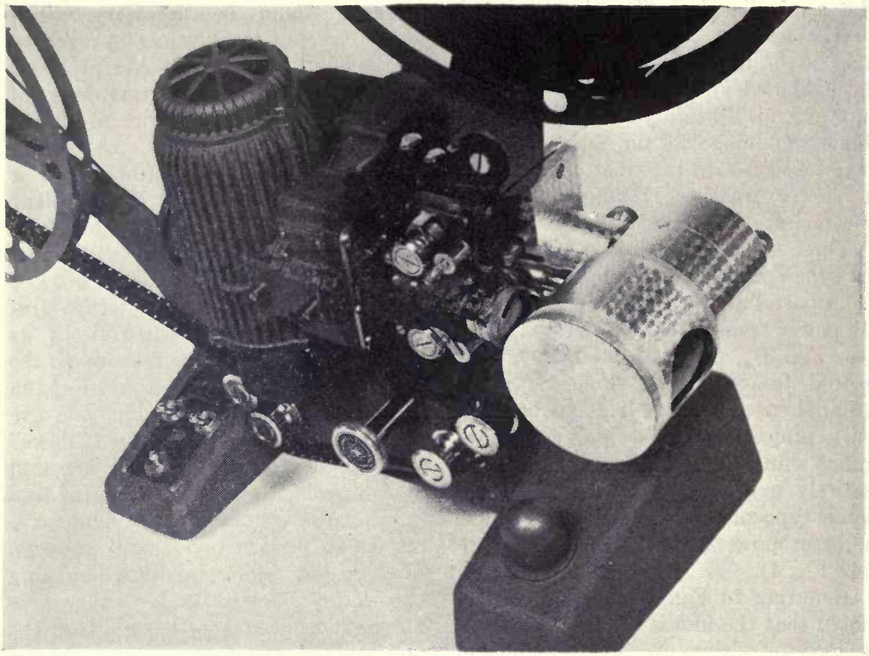


Fig. 5. Direct-drive polarizer attachment mounted on Bell & Howell Showmaster Projector. This projector is equipped with the Morgana movement.

quality standard for 16-mm projection. The alternate-frame principle also facilitates projection through a single undisplaced axis from the projector aperture straight to the screen. Because of this feature there is no need to register manually the two images on the screen. Registration, on the other hand, is accomplished during filming or during processing and is accurately maintained in the film gate aperture of the projector and likewise on the screen. Effects, which should result from calculated lateral image displacement, are faithfully reproduced on the screen. In contrast the usual type of beam splitter displaces the axis of the images, and reregisters the stereo images separately. As a result the effects intended at the time of the photography are seldom accurately reproduced on the screen. In addition, and because of projectionists' errors, vibrations, etc., the beam splitter system can be the cause of misregistration which in turn results in eyestrain. Unfortunately, many believe, unjustly, that such eyestrain is characteristic of any and all three-dimensional pictures.

Although the Morgana movement accomplished wonders in solving the flicker problem, it introduced a limitation in the allowable rate of action of moving objects. Any fast subject movement, especially laterally, appears considerably jumpy on the screen. The reverse shuttling feature of the Morgana movement, of course, is directly responsible. To be sure, this new bug is troublesome, but it is not nearly as detrimental as was the flicker condition.

PRODUCING THE ALTERNATE-FRAME STEREO FILM

Single-axis projection, as described in the preceding section, requires that the registration and/or image displacement problem be considered and dealt with during the making of the film. To accomplish this properly certain practices must be adhered to.

Referring to the diagram, Fig. 6, L and R represent the left and right viewpoints of the taking camera. If two cameras are used, L and R represent the optical center of the left and right camera lenses respectively. (The frames of the two films in this case are printed alternately by a special effects printer on a single positive film.) If one camera with a beam splitter is used, L and R represent the optical centers of the optically split and displaced lens. The distance between the two optical centers is the interocular. The field coverage of the left lens is the cone bounded by the two lines XL and YL. The common plane XY, where the cone of coverage of each lens is coincident, is the datum plane. It represents the position in space where objects photographed, and projected, appear to lie in the plane of the projection screen. The reason for their appearing to lie in the screen plane is simply that there exists no lateral displacement between their left and right images on the film. Thus they exactly superimpose on the screen and our eyes "triangulate" them in that position.

[The position of the datum plane, as can be seen by the diagram, is fixed always at the point where the axis of Lens L intersects with the axis of Lens R.] The distance between the datum plane and the camera lenses is the convergence distance. The convergence angle is the angle between the axis of the two lenses. The far image displacement distance (D) is the distance at the datum plane between rays, entering lens L and lens R, which have

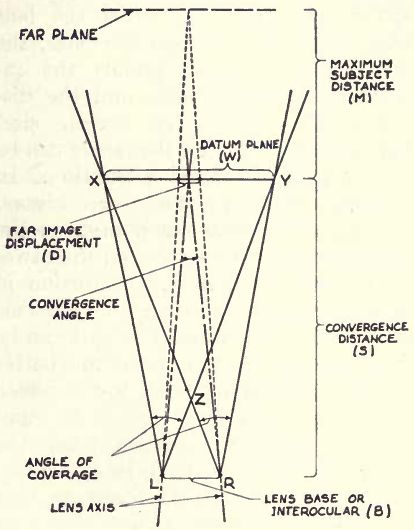


Fig. 6. Diagram of factors involved in alternate-frame stereo motion picture photography.

emanated from a point on the farthest object within the field of coverage.

Under certain conditions the distance to the farthest object must be limited, as for example when shooting close-ups or when using an interocular greater than the normal interpupillary distance $2\frac{1}{2}$ in. Assuming a maximum projection screen width of 70 in. and a maximum projection distance of 30 ft, (D) should not exceed more than $^{1}/_{28}$ the total width of the datum plane XY. This is calculated from the maximum image displacement allowance on the screen of $2\frac{1}{2}$ in. divided into 70 in. or the screen width. It can be seen that under close-up conditions, some type of limiting plane or backdrop must be used. The distance to this plane, or to infinity when the photographic conditions are normal, is the maximum subject distance (see Fig. 6).

Effects and Rules

The true size, shape, position and relation to one another, of objects in space can exist only when the lens base equals the average eye base, the convergence distance equals the intended viewing distance and the distance XY equals the screen size. Obviously this implies that there can be only one correct viewing position. In practice, however, the area of good viewing positions is comparable to the viewing conditions associated with two-dimensional projection. Distortion in depth is noticeable in extreme positions but there seems to be little that can be done about it except to move to a better position. Positions closer to the screen cause the depth dimension to be compressed, positions further from the screen cause the depth to be elongated. It can be seen from the foregoing that in 16-mm work where conditions of projection are relatively stable, i.e., 2-in. lens projecting from 20 to 25 ft onto a 45 × 60 in. screen, that normally the camera conditions could be fixed. This would simply require 2-in. lenses 2½ in. apart converged on a point 25 ft from the camera. These conditions then would permit shooting any subject that might lie all within the space XYZ Fig. 6, or all or parts of which might lie beyond the datum plane. In projection, assuming these camera conditions, the subject matter will appear in the same relative position with respect to the screen as it did with respect to the datum plane.

Some of the rules that should be adhered to are as follows:

1. For normal results the axis of the two viewpoints should be converged so as to intersect at a distance from the camera equal to the average intended viewing distance.

2. All subject matter that will appear on the screen should be kept, if possible, in sharp focus. Plain backdrops need not be in focus, but should be used if possible, to hide out-of-focus subject matter.

3. All objects photographed on the camera side of the datum plane should be contained within the common portion of the two cones XLY and XRY; hence they will not appear to touch the boundaries of the screen when viewed. Thus, objects appearing in front of the screen should not have any visible means of support, except possibly from a position behind the screen. Adherence to this rule is important, otherwise the brain will have difficulty in dealing with impulses that, on the one hand, signify that an object is actually between the observer and the screen, and on the other hand, signify that this same object is being partly obliterated by the boundaries of the screen.

4. The subject matter should be rotated or the camera moved around it whenever possible, so as to incorporate the "movement" factor of depth perception.

5. In respect to close-ups, if the subject cannot be contained in the space XYZ, the axes of the camera lenses should be converged on a point just in front of the subject. This will cause the subject to appear just beyond the screen plane when viewed, and increased in size. The increase in apparent size of the subject in this case will be directly proportional to the convergence distance divided by the viewing distance.

Since most close-ups require converging on a point closer than the intended viewing distance, they will also require an artificial far plane or backdrop. This is necessary, first, to prevent the far image displacement distance (D) from increasing beyond 2½ in. on the screen when projected, and, second, to eliminate unwanted out-of-focus subject matter.

The formula for determining the maximum subject distance (M) when the convergence distance (S) is less than the intended viewing distance, or

when the interocular is greater than $2\frac{1}{2}$ in. is derived as follows:

Referring to the diagram (Fig. 6), it may be seen that:

$$\frac{M + S}{D} = \frac{M}{D} \text{ or } M = \frac{DS}{B - D}$$

It has been previously shown that D could not be greater than $^1/_{28}$ of the distance XY. Thus, for example, if

S = 60 in., XY = 14 in., and B = $2\frac{1}{2}$ in.

then

$$M = \frac{\frac{14}{28}(60)}{2\frac{1}{2} - \frac{14}{28}} = 15 \text{ in.}$$

THE ALTERNATE-FRAME STEREO CAMERA

Four different cameras have been adapted by the author for alternate-frame stereo motion picture photography. With this equipment a wide variety of applications has been possible. It should be noted that the mission of the Stereo Unit, AMC Photographic Service Center, Wright-Patterson Air Force Base, is to accomplish any type of stereo photography which it might be called upon to perform.

16-Mm cameras which have been adapted for alternate-frame stereo photography are; the Bell & Howell Filmo (Fig. 7), the Eastman High-Speed (Fig. 8), an Eastman High-Speed with Graham transmission (Fig. 9), and a Cine Special. Each of the cameras listed now accomplishes the requirement of exposing the right and left stereoscopic images on alternate full frames of the film.

Cameras equipped with barrel-type shutters lend themselves conveniently to alternate-frame stereo adaptation. In such cases the barrel-type polarizer principle can be incorporated as an integral part of the shutter. A split Polaroid filter on the lens of the camera, then, provides for alternate selection of the right and left views on each 180° rotation of the shutter. The axis of polarization of either half of the split filter on the lens is 45° to the vertical and opposed by 90°. Since the axis of polarization of the filter in the shutter is also on a 45° diagonal, it acts, together with the split filter on the lens, to eclipse alternately either half of the latter during each half revolution (see Fig. 10). Thus when a beam splitter is centered in front of the lens the displaced right and left views therefrom, entering their respective halves of the lens, are recorded selectively on alternate frames of the film. This method of selection is particularly advantageous in high-speed work where, otherwise, a mechanical shutter selector would be impractical.

High-Speed Adaptation

Both of the Eastman high-speed cameras illustrated in Figs. 7 and 8 are equipped with a Polaroid filter mounted in the barrel shutter compensator. Figure 10 shows this type of compensator positioned over a split Polaroid filter. Note that the left half of the filter as seen through the barrel of the compensator has been eclipsed. If the compensator had been rotated 180° from the position shown, the right half of the filter would have been eclipsed. The left side would have remained clear. The compensator shown was specially constructed by Eastman Kodak Co. It contains a sheet of Polaroid mounted between two optical glass plates. The refracting action of this optical assembly corresponds to the specifications of the standard Eastman high-speed compensator. Since there are no additional moving parts involved in the high-speed stereo adaptation, the camera can be operated at its maximum speed. There is one disadvantage in

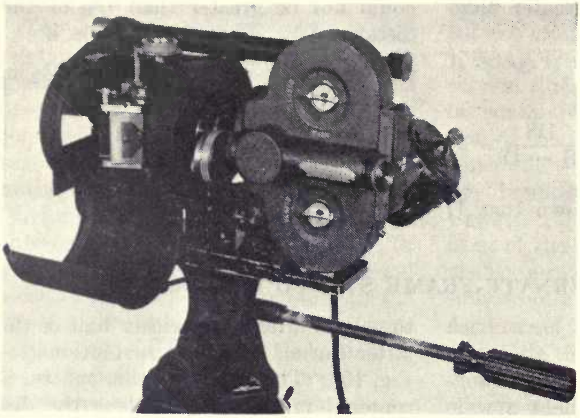


Fig. 7. Motorized Bell & Howell Filmo Camera with stereo alternate-frame selector.

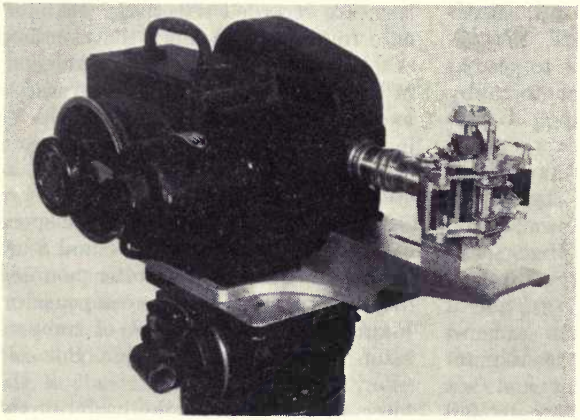


Fig. 8. Eastman high-speed camera equipped for alternate-frame stereo photography.

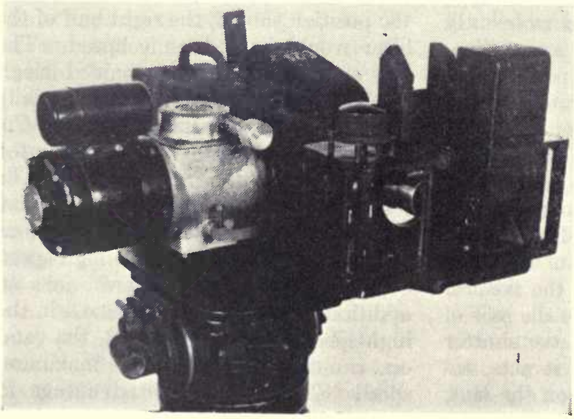
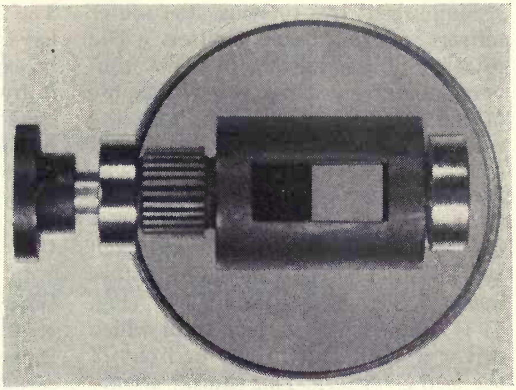


Fig. 9. Eastman high-speed camera equipped with Graham transmission and beam splitter for stereo photography at constant speeds from 0 to 176 frames/sec.

Fig. 10. Polaroid compensator used in the Eastman high-speed camera shown positioned over a split polaroid filter which is used on the lens of the camera.



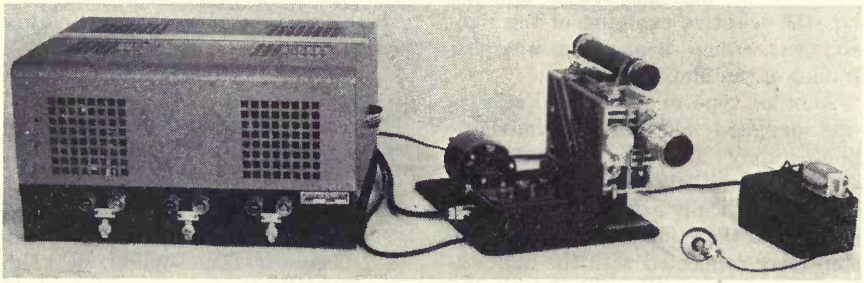


Fig. 11. Time-lapse equipment including step relay and solenoid-actuated lens attachment which alternately exposes right and left apertures of a stereo diaphragm over the lens.

this system, however, in that two stops of light are lost through the Polaroid filters.

Because of the simplicity of the optical selection of right and left images provided by the barrel shutter, one of the Eastman high-speed cameras shown (Fig. 9) was modified to provide constant frame speeds over a range from 1 to 176 frames/sec. As can be seen, this was accomplished by powering the camera with a Graham transmission. Some of the scenes in the film (shown at the Convention) were shot with this camera at the normal speed of 24 frames/sec.

The beam splitters shown positioned in front of the lenses of the cameras in Figs. 8 and 9 are interchangeable, i.e., they can be used with either camera. The beam splitter shown in Fig. 8 in addition is used in the attachment shown on the Bell & Howell Filmo (Fig. 7). This provides a choice of either a 2½-in. interocular or a 6-in. interocular. The latter is used with the 4- and 6-in. lenses to maintain normal depth proportions. The 6-in. beam splitter is equipped with a parallax-free view-finder which incorporates a half-silvered beam displacer. This feature provides a method of accurately registering the right and left beam-splitter images with respect to the central view-finder image. The actual registration of the separate images is

accomplished by rotating the outer mirrors of the beam splitter. The rotation of the mirrors in effect converges or diverges the two viewpoints of the system in accordance with the rules previously outlined.

Mechanically Operated Selectors

At normal and slower speeds mechanical shutters can be operated and synchronized by the camera or by other means. The Filmo mechanism (Fig. 7) is coupled with a gear train which drives a 180° shutter out in front of the beam splitter. This shutter accomplishes the same task as the optical selectors in the high-speed cameras, i.e., the selective exposing of the right and left stereo images on alternate frames of the film.

Another type of mechanical selector was designed for use in time-lapse photography (see Fig. 11). Here advantage was taken of the pulse timer which periodically actuates both a light circuit and the camera. A solenoid and step relay connected with the light circuit actuates a small oscillating shutter at every other impulse. The shutter is mounted on the lens and positioned over one of two apertures in a diaphragm also over the lens. Thus on every other impulse the shutter oscillates to a position over the normally open aperture causing the exposure to be made through the normally closed aperture. The apertures in this particular case have a displacement of ⅝ in., but can be expanded by placing a beam splitter in front of the shutter assembly. The stereoscopic time-lapse scene in the film shown was made with this equipment using a 50-mm lens and a ⅝ in. interocular.

Conclusion

In view of the versatility of applications possible with the alternate-frame technique, and in view of the full-frame quality possible therewith, and assuming that the few remaining problems can be ironed out, this system may prove to be a practical as well as a valuable medium of synthesizing natural vision.

References

1. H. E. Ives, Traill-Taylor Lecture before the Royal Photographic Society, 1933.
2. G. W. Wheelwright, "Possibilities of stereoscopic motion pictures," *Optical Developments* (Land-Wheelwright Laboratories, Boston, Mass.), vol. 8, no. 9, Sept. 1938.
3. J. A. Norling, "Three-dimensional motion pictures," *Jour. SMPE*, vol. 33, pp. 612–634, Dec. 1939.
4. U.S. Pat. No. 2,478,891, assigned to R. V. Bernier, Dayton, Ohio.
5. J. A. Dubray, "The Morgana Color Process," *Jour. SMPE*, vol. 21, pp. 403–412, Nov. 1933.

Continuous Processing Machine for Wide Film

By Herbert E. Hewston and Carlos H. Elmer

A new continuous processing machine for wide film carries the principles of motion picture film processing into the field of processing black-and-white film ranging in width from 70 mm to 12 in. Details of design and operation are outlined.

At the Naval Ordnance Test Station many kinds of quantitative data from test firings of rockets and guided missiles are recorded on special cameras which use film wider than 35 mm. These cameras include the Bowen Ribbon-Frame camera, described by Green and Obst,[1] which uses 5½-in. film; K-17 aircraft cameras modified for ground-to-air recording which use 9½-in. film; and various types of oscillographs which use film up to 12 in. in width. Until recently, these film records have been processed in small-capacity aerial roll-film processing units of the Smith-Fairchild or Morse types. After processing, the films were dried on a revolving drum.

Since a single day's test firing may result in exposure of several thousand feet of wide film, the inability of small tank processing to handle this material was evident. This was especially true because of the rigorous time limits imposed on the processing laboratory so that the film records might be examined in time to change subsequent firing conditions.[2] There was also a need for a processing method which would provide greater uniformity in the finished film product than was possible with the small tank method. To meet the requirements of this Station, design of a continuous wide film processing machine was initiated in 1948.

In June, 1949, the design and performance specifications had been formulated. The contract for construction was awarded to Imagineering Associates, Inc., of Pasadena, Calif., where the machine was constructed under the general supervision of Irving W. Akers. The machine was delivered to this Station in December, 1949. After installation and some subsequent modification, it was placed in production during September, 1950.

The components are shown schematically in Fig. 1. The machine is divided into three main parts: the darkroom wet-end section, the wash section and the dry box. Figure 2 shows the entire machine.

Presented on April 30, 1951, at the Society's Convention in New York by Herbert E. Hewston and Carlos H. Elmer, Photographic Laboratory Branch, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.

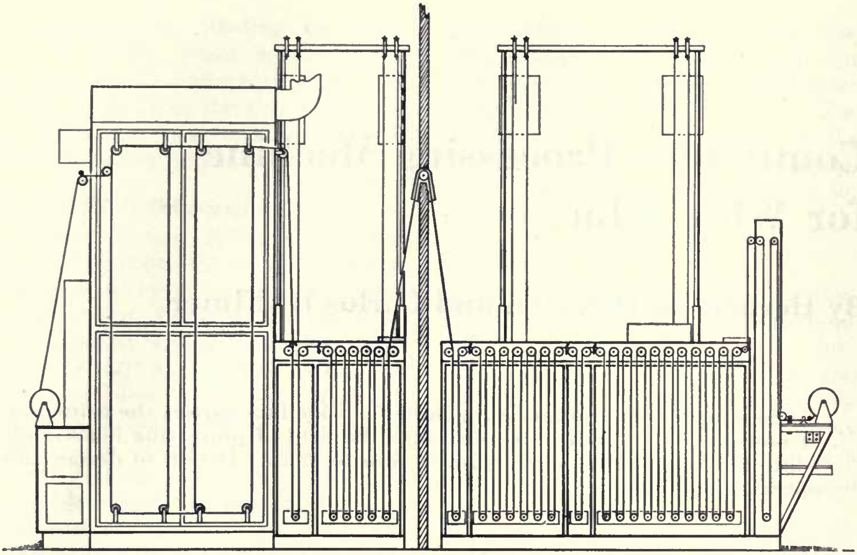


Fig. 1. Schematic diagram of continuous processing machine for wide film.

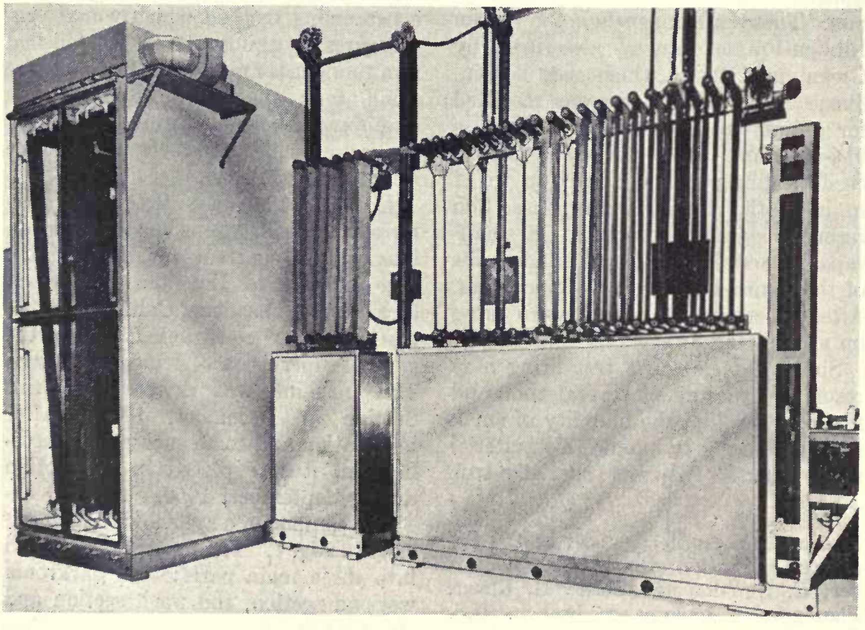


Fig. 2. Continuous processing machine for wide film.

Each of the three sections is driven by a separate synchronous motor directly coupled to a Graham transmission. The three drive units are selsyn-coupled to speed controls mounted on the take-up end of the dry box. Machine speed is governed by a metering roller immediately preceding the developer tank. The rest of the top rollers are overdriven through friction clutches from a flat endless belt which is driven from the metering roller. Top rollers are supported by fixed stainless steel tubing which is connected by flanges to the main roller rack support beam. These top rollers ride on plain bearings made of nylon. The roller rack assemblies are counterbalanced and attached to hoists which raise the rack assemblies a maximum of 6 ft to bring the bottom rollers above the tops of the tanks for maintenance purposes. The bottom idling rollers in the wet end are mounted on bearings made of Teflon, a Du Pont plastic with low friction properties. Nylon bearings were first used at these points, but difficulty was encountered from friction between the roller shafts and the bearings. The wet film would tend to slide across the rollers without turning them. The substitution of Teflon bearings eliminated this difficulty. The dry box drive is also applied on the top rollers by spring belts from friction-driven shafts.

The loading ledge, shown in Fig. 3, is equipped with an automatic run-out brake and audible alarm. As the film end leaves the feed-in reel the brake is applied, the loading elevator starts to rise, and an audible alarm is sounded. If the elevator rises completely to the top, the machine drive will stop.

The film loop length in the developer tank may be remotely adjusted from the control panel from a maximum extension of 5 ft to a minimum of 2½ ft (linear film length of 10 ft and 5 ft respectively), or any intermediate point between these limits. This adjustment in loop length, which can be made while the machine is in operation, permits a wide variation in developing time at a given machine operating speed. Film loops may also be dropped to further shorten the developing time. The adjustable loop feature is illustrated in Fig. 4, while Fig. 5 shows the graph from which developing times are determined. Temperature control of the developing solution is obtained by forced circulation of the solution through a heat exchanger made up of alternating solution and tempered water baffles. The solution flow through the heat exchanger is indicated by the arrows in Fig. 6. These heat exchanger baffles can be readily dismantled for cleaning. After temperature conditioning in the heat exchanger, the solution re-enters the developing tank through jet headers,

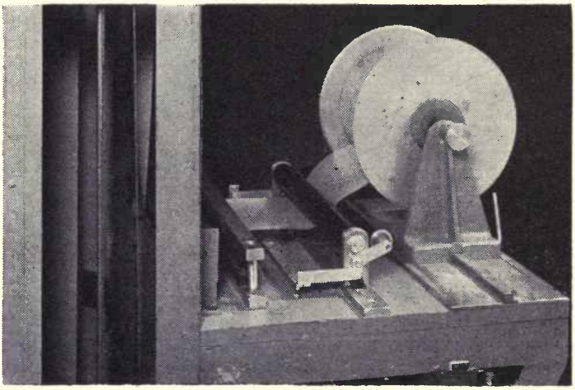


Fig. 3. Loading ledge of machine, with automatic run-out break and audible alarm.

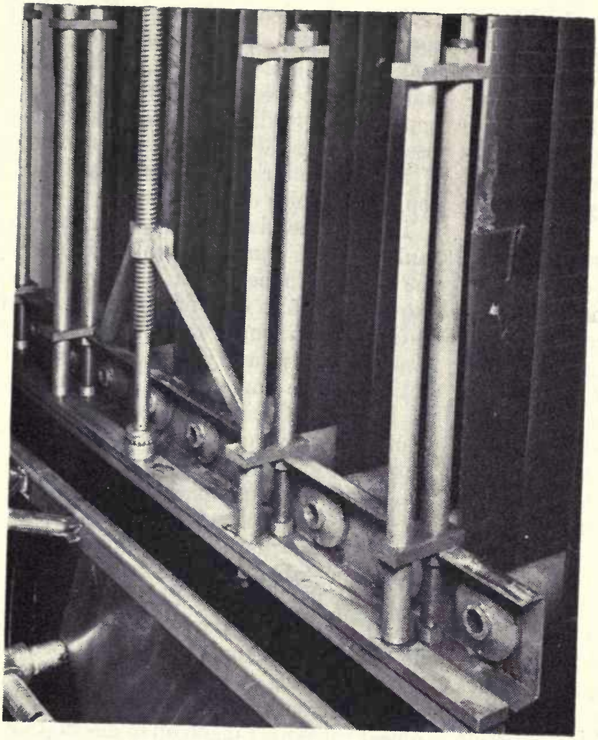


Fig. 4. Adjustable loop mechanism.

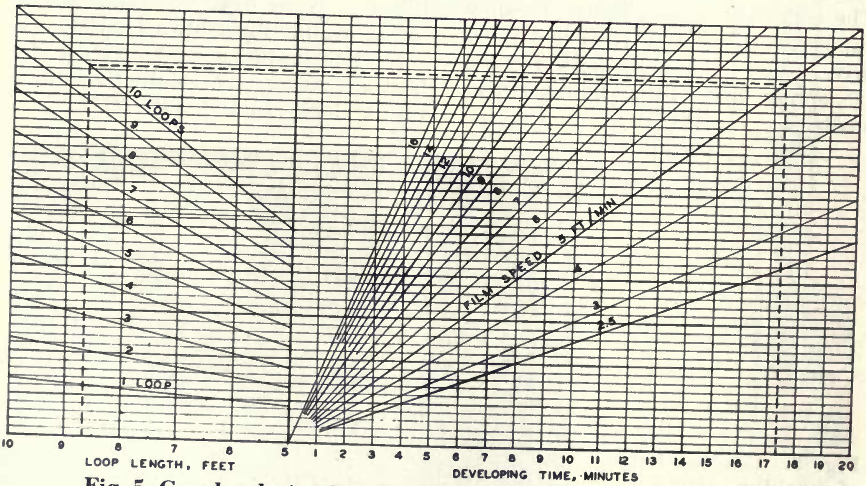


Fig. 5. Graph relating loop length, number of loops, film speed and developing time

thus producing agitation. The developer tank has a capacity of 225 gal, and is followed by a 39-gal stop bath tank and a 137-gal hypo tank. The fixing solution is temperature controlled by forced circulation through a section of the same heat exchanger. The hypo tank is followed by a 39-gal rinse tank, after which the film goes from the darkroom through a light-tight film pass to the wash tank. Figure 7 shows the dark-end tank section.

The 115-gal wash tank can be filled to 30, 60 or 90% of capacity, or can be operated empty with complete spray washing. Jet action is provided by the spray headers either above or under water. The wash water is obtained from the special Photographic Laboratory supply of temperature-controlled water. Since the line water frequently

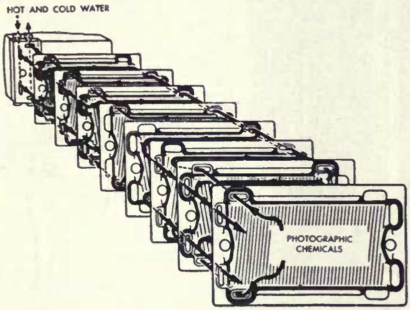


Fig. 6. Flow diagram for plate section of heat exchanger.

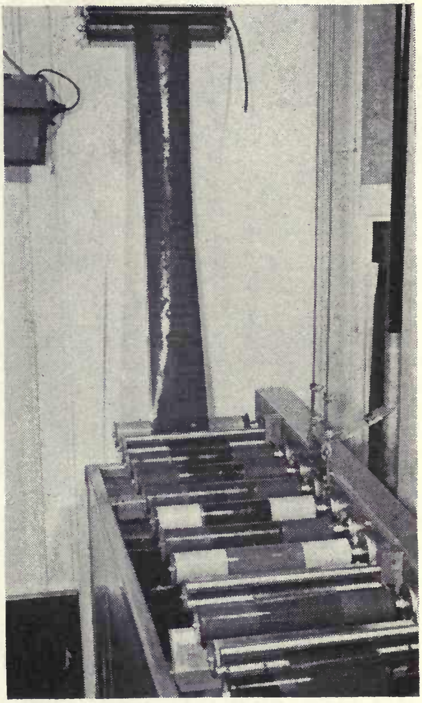


Fig. 7. Dark end roller rack in lowered position, ready for processing.

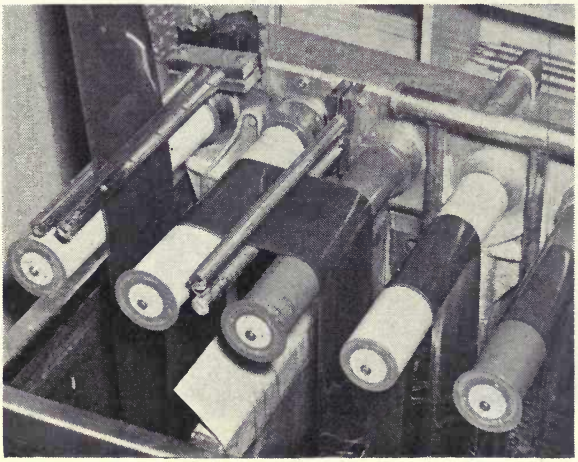


Fig. 8. Typical squeegee installation.

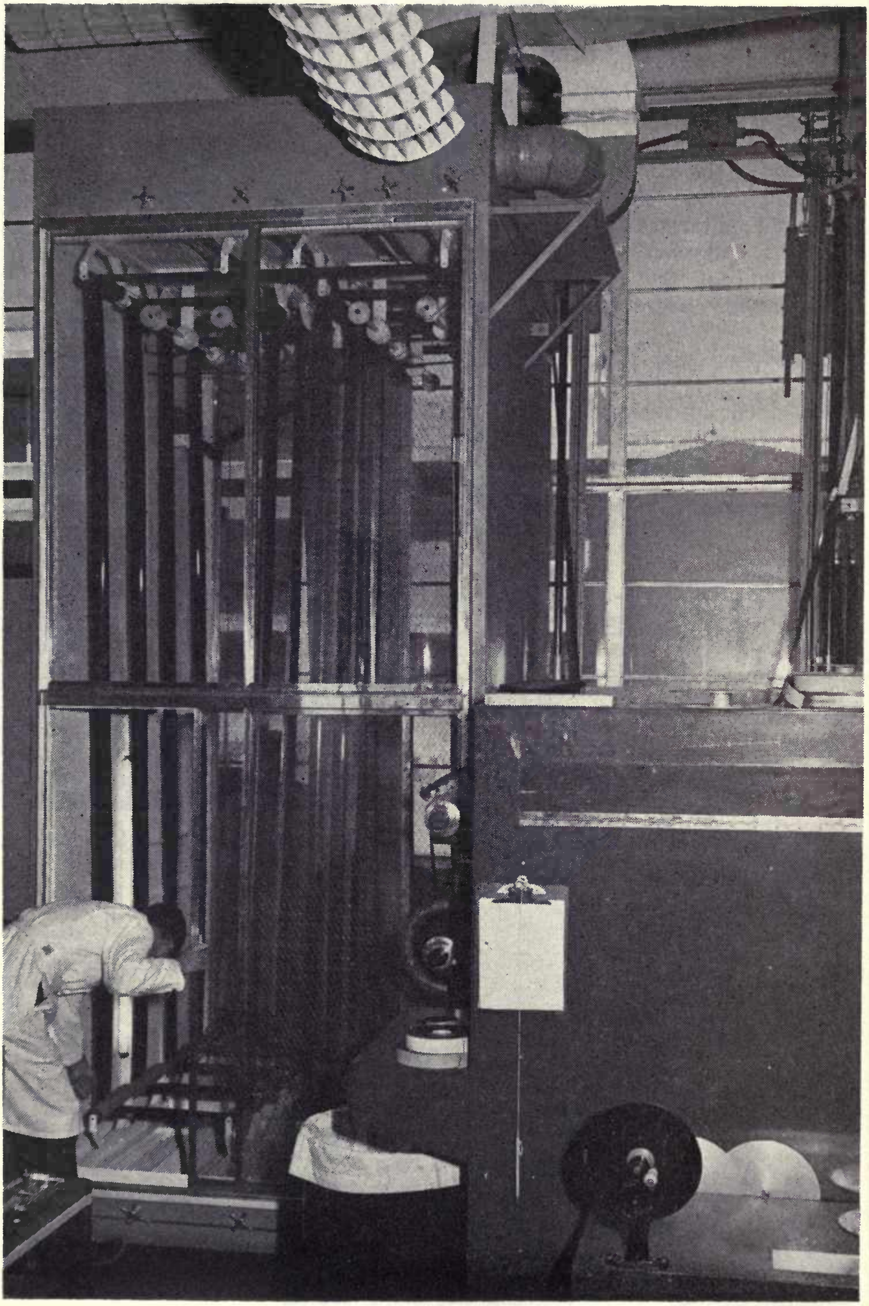


Fig. 9. Dry box.

reaches 85° F during the summer in this desert locality, a chilled water supply is required for proper record-film processing. The wash tank is followed by another 39-gal rinse tank containing an aerosol solution.

A rubber knife edge squeegee is located between each two liquid tanks

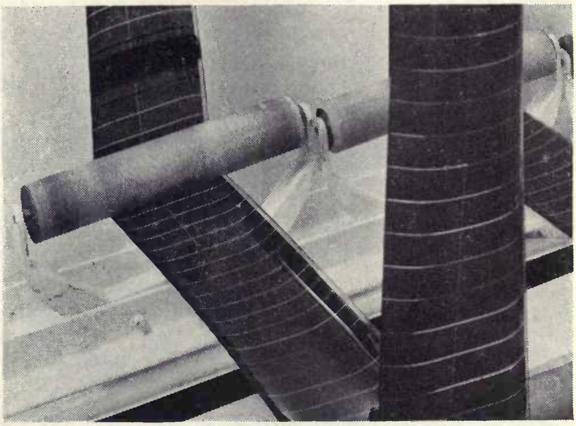


Fig. 10. Angle of film progression in drying cabinet.

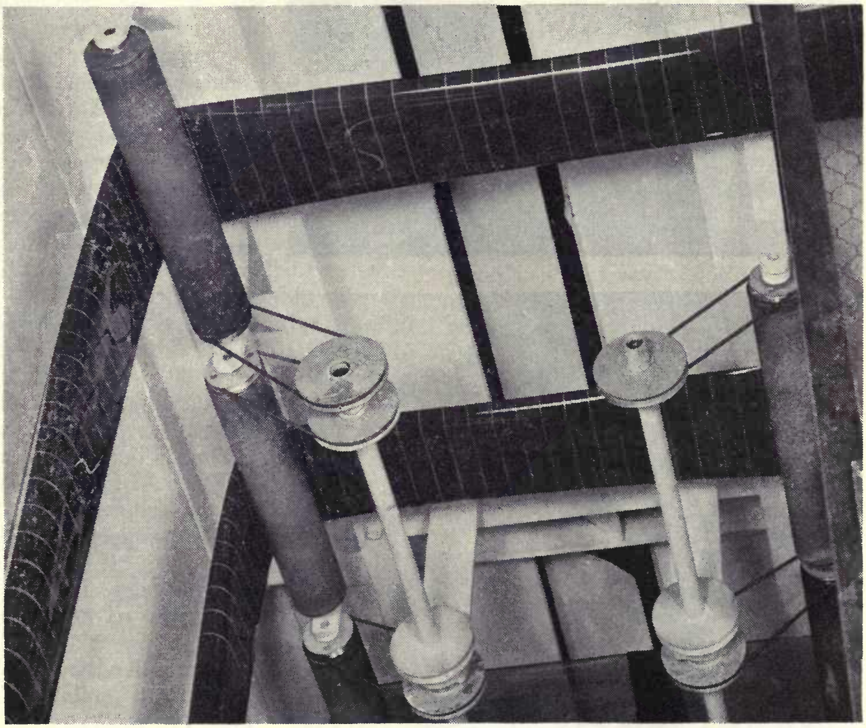


Fig. 11. Dry-box top film rollers.

and between the final rinse tank and the dry box. A typical squeegee installation can be seen in Fig. 8.

The dry box is shown in Fig. 9. While the film's emulsion touches the submerged bottom rollers in the liquid tanks, roller contact is made only with the film base in the dry box. This is

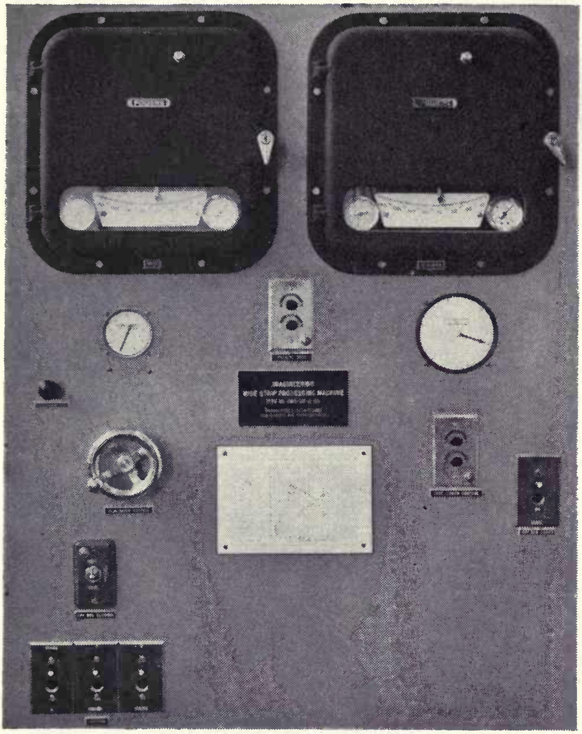


Fig. 12. Machine's control panel.

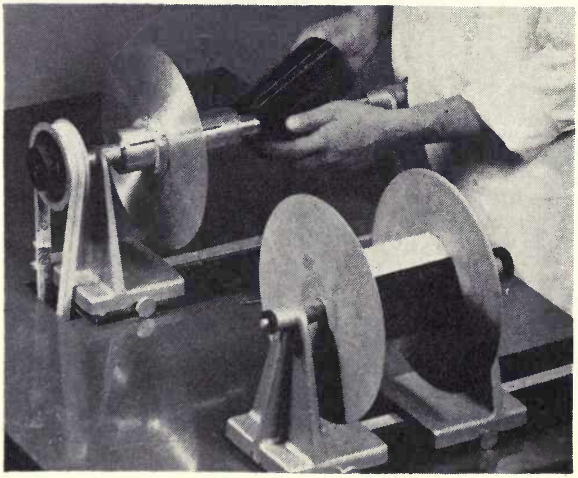


Fig. 13. Power-driven rewind assembly.

accomplished through the mounting of the dry-box rollers on individual shafts at such angles as to permit 14 in. of side movement per film wrap. Two wide passes of four wraps each are made through the dry box, which is 6 ft square and 14 ft in height. This configuration, which is not ideal from the standpoint of operating efficiency, was made necessary by space limitations in the laboratory. The angle of film progression in the drying cabinet is shown in Fig. 10, while Fig. 11 shows the manner in which dry-box top film rollers are driven through spring belts from drive shafts which are parallel to the roller centers. The drive shafts are chain driven through friction clutches.

Details of the control panel are shown in Fig. 12. The control panel contains, at the top, Powers temperature-control instruments for the developer and hypo solutions, and, in the center, the machine drive start and stop button, and the developing time graph. A tachometer, speed-change control wheel and lock button, a dry-box blower switch, and dry-box heater selector switches are located at the left. On the right are the developer-rack loop-length indicator, loop-length control buttons which raise or lower the bottom-roller assembly, and the dry-box light switch.

The film take-up assembly, like the feeding assembly, is adjustable in width from 35 mm, the size of the leader, to 12 in. The 1,000-ft rolls of processed film are broken down into individual rolls for delivery, using a special power-driven rewind assembly, which may be seen in Fig. 13.

The machine's operating speed ranges from a minimum of 3 ft/min to a top speed of 15 ft/min. A speed of 10 ft/min is generally used. Developing time can be varied from 1 min to 20 min.

Since the machine has been placed in production, it has processed well over 100,000 ft of wide film, and daily runs of more than 3,000 ft are not uncommon. As a comparison, 3,000 ft of 9½-in. film is equal in area to 21,000 ft of 35-mm film.

A definite improvement in consistency of processing quality has been achieved, and the machine has proven to be of great assistance in the rapid production of wide-film records depicting the progress of our ordnance development and testing programs.

It had been planned that the new machine would also be used as a research tool in the investigation of such matters as the effects of various processing conditions upon dimensional stability of wide-film bases, etc. To date, the volume of processing has not permitted this program to be undertaken, but it is expected that some findings in this field may be obtained within the next year.

During the testing and operating of the new wide-film machine, many problems have been encountered which might be unique to the field of machine processing of film greater in width than 35 mm. While several of these problems have been satisfactorily overcome, others remain to be solved. Besides providing this Station with a means of increasing its output of wide-film records, it was assumed that the construction and use of such a machine would also provide a fund of information on this subject which might be of value to others planning installation of similar facilities.

(All photographs are official photographs of the U.S. Navy.)

References

1. E. E. Green and T. J. Obst, "Bowen ribbon-frame camera," *Jour. SMPE*, vol. 53, pp. 515–523, Nov. 1949.
2. C. H. Elmer, "Photography in the rocket-test program," *Jour. SMPTE*, vol. 54, pp. 140–148, Feb. 1950.

Discussion

H. W. Sachs: With regard to the contour rollers which are cylindrical in the wet section, does it facilitate the operation if the rollers in the dry box have a very slight crown to them?

Mr. Hewston: That was one of the problems we overcame simply by reinforcing everything. We found if everything was nice and true, so was the film.

Roy Wolford: Have you attempted to use the same principle in processing long lengths of paper?

Mr. Hewston: We are processing paper on it, as well as film.

Mr. Wolford: At the same maximum running speed?

Mr. Hewston: Yes.

Norman Exley: What is the purpose of the provision for operating with the wash tanks either empty or partly full?

Mr. Hewston: We have found that more turbulence is produced by using a spray in a tank that is empty. In other words, the film is not immersed but you get some soaking.

Mr. Exley: What is the usual method of operation?

Mr. Hewston: We have operated it several ways. We find maximum efficiency at about 30% of full. You get a little bit of soaking and a lot of jet action on the surface.

John Crabtree: What material is used for the gaskets? Also, how long does it take to load the machine?

Mr. Hewston: The gaskets (heat exchanger) are Neoprene and they are used for the same purpose as any others. It is the only means of retaining the solution within the confines of the chamber. The plates themselves are corrugated to give a certain definite distance between each plate.

The other question on loading: It is 600 feet through. At 10 feet per minute the time through would be one hour. The time to load on a new roll of film, that is to splice on a new roll, is about 20 seconds.

Anon.: Explain the use of the gaskets in the heat exchanger.

Mr. Hewston: To include or exclude ports in the baffles and to establish the desired flow of two separate solutions, namely, the tempered solution and the solution being tempered.

Anon.: Were tape splices used?

Mr. Hewston: Yes.

Mr. Exley: Is developer activity maintained by batchwise or continuous replenishment?

Mr. Hewston: Continuous replenisher controlled through chemical analysis.

Slide Rule for Analyzing High-Speed Motion Picture Data

By Karl W. Maier

In mechanics research, evaluation of high-speed motion picture records involves several basic calculations which have to be repeated very often. The Springfield Armory has developed a special slide rule which will mechanically perform these computations, as well as some precalculations before taking the picture. It is believed that the proposed slide rule permits more rapid evaluations with fewer errors and with less highly trained personnel.

This analysis covers standard 16- and 8-mm motion picture films, with the standard timing marks, 1000 or 60 timing units per second, as used in mechanics research (Fig. 1).

A motion picture engineer often has to make basic calculations in evaluating a given high-speed motion picture record. Of special interest are the operating time of a certain machine part and the cyclic rate of the mechanism to be investigated. Direct counting of the corresponding number of timing units is too tedious when the operating time, as is usual, extends over a great number of frames. Therefore, it is better instead to count the corresponding number of frames and the operating time is calculated from this. Although the formulae involved are comparatively simple, considerable time is consumed in reading values from the film as well as in the elementary calculations, and thus, series investigations, desirable for one reason or another, would appear to be impractical. Furthermore, the motion picture engineer must determine optimum operating conditions for the camera before taking a picture. In order to reduce time and errors, a mechanical method of computation would be of advantage and solve both problems.

R. F. Ledoux, head of the Springfield Armory Photographic Laboratory, expressed the desire for an instrument that would fulfill such requirements, and a beginning was made. First, charts were used and from them there was finally evolved a special slide rule, which should satisfy a long-felt need for more rapid evaluations. Although this slide rule was originally intended for weapon research and development, it is believed that it can be used equally well in the entire field of mechanics research. The first model has been fabricated and tested by the Photographic Laboratory of Springfield Armory, and has proved to be a great time saver. A patent application has been filed.

This proposed evaluation method is

Presented on May 3, 1951, at the Society's Convention at New York, N.Y., by Karl W. Maier, Springfield Armory, Springfield 1, Mass.

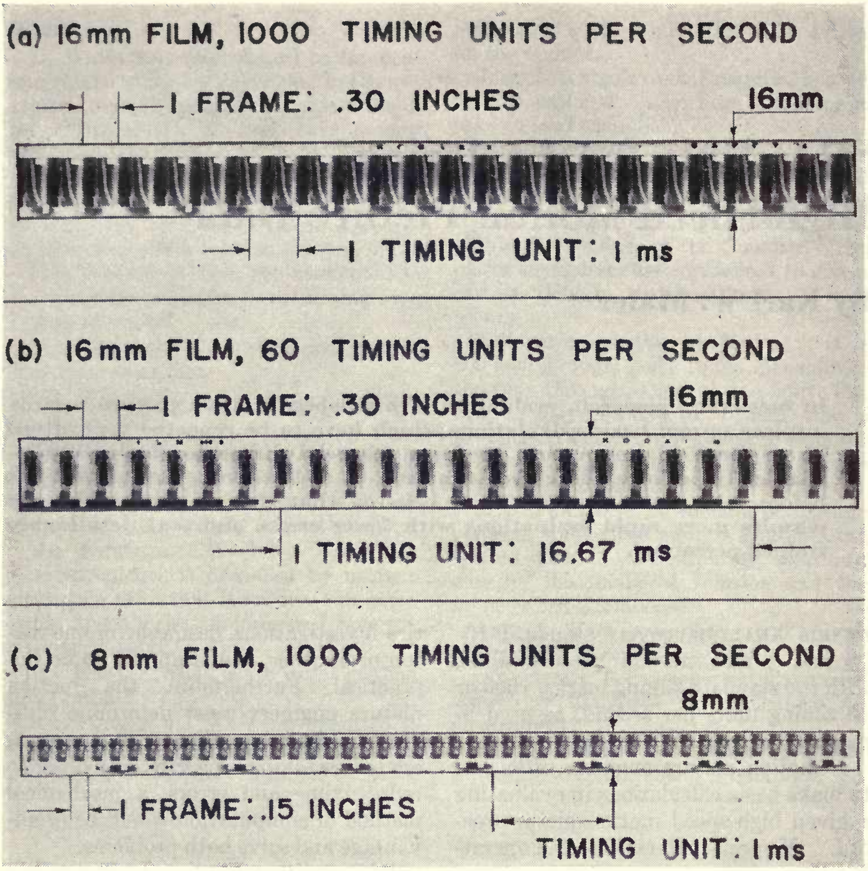


Fig. 1. Standard films with timing marks.

based on a simplified reading of values from the film. For evaluation purposes, the length of the film is divided into parts, over which the original film velocity (during film run in the camera) can be considered constant, depending on the acceleration of the film and accuracy desired. Within such a part of film, any time interval and the corresponding number of frames are in constant proportion. This can be designated as the "frame time," i.e., time value of one frame.

The number of frames representing a certain operating time is counted either visually (when small) or by means of a mechanical frame counter, the latter being either on the projector or separate. The height of one frame, 0.30 in. for 16-mm film and 0.15 in. for 8-mm film, is used as the unit of length for the film, thus eliminating any length measurements in the direction of film motion by means of a scale.

With regard to time, only small time intervals consisting of a few timing units are counted visually. Greater time intervals are calculated by means of the slide rule, using the frame time and the corresponding number of frames.

Nomenclature

Note: Whenever film velocities or time intervals on the film are given, the film run in the camera when the picture was taken is meant; the velocity of the film when being projected is not of interest here.

Symbol	*Description of Symbol*	*Unit*
N	Any number of frames or pictures in a given part of the film	frame
N′	Number of shots in a burst	shot
t	Any time interval of film	ms
t_1	Frame time, i.e., time value of one frame during the film run in the camera	ms/frame
T	Total running time of film	sec
T′	Duration of a burst fired or time to be recorded	sec
i_{1000}	Any (whole) number of timing units when using 1000 timing units per second (frequency 1000)	1 ms
i_{60}	Any (whole) number of timing units when using 60 timing units per second (frequency 60)	16.67 ms
v	Velocity of film in the camera	ft/sec
V	Velocity of film in the camera	frames/sec
v_{max} (V_{max})	Maximum film velocity near end of film run in the camera	ft/sec (frames/sec)
$\bar{v}$ ($\bar{V}$)	Average film velocity over total running time	ft/sec (frames/sec)
v_{min} (V_{min})	Minimum film velocity permissible for sharp pictures	ft/sec (frames/sec)
n	Cyclic rate of a mechanism	rpm
v^*	Maximum velocity of moving machine part	ft/sec
$\bar{v}^*$	Average velocity of moving machine part over given travel distance	ft/sec
s	Travel distance of machine part	in.
w	Width of field in the distance of moving parts covered by the effective width of the film (see Fig. 3)	in. (ft)

To establish the scales of this slide rule, some preparatory work, such as defining characteristic values and analyzing mathematical relationships used in the basic computations, had to be done first.

Basic Tasks for Evaluating Film Records and Formulae Used

With a given motion picture record, the relationship between a certain time interval and the corresponding number of frames is of general interest and will aid in standardizing evaluations. This time-length relationship can be indicated either by the "frame time" in ms/frame, or by the film velocity measured in ft/sec or frames/sec. Both values vary over the length of the film. This brings up the following questions:

What is the *frame time*, t_1, at any point of the record? N frames of the film may correspond to the time t, or i_{1000} timing units or i_{60} timing units (i_{60} and i_{1000} are whole numbers); the frame time then becomes:

$$t_1 = \frac{t}{N} = \frac{i_{1000}}{N} = \frac{50 \cdot i_{60}}{3N}, \text{ in ms/frame. } (1)$$

For example: When 5 timing units of the 1000-cycles timing correspond to 8 frames, the frame time then becomes:

$$t_1 = 0.625 \text{ ms/frame.}$$

What was the *film velocity* in the camera, v, in ft/sec (or V, in frames/sec), at any point of the given record? N frames may correspond to the time t, or i_{1000} timing units or i_{60} timing units, then the film velocity is:

$$V = \frac{1000}{t_1} = \frac{1000 \cdot N}{t} = \frac{1000 \cdot N}{i_{1000}} = \frac{60 \cdot N}{i_{60}}, \text{ in frames/sec.} \quad (2)$$

For example: With 8 frames in i_{1000} = 5 timing units, a film velocity of 1600 frames/sec results. The corresponding film velocity v, measured in ft/sec, as well as the relationship between v and V, depends on the type of film.

16-Mm Film:
$$v = \frac{25}{t_1} = \frac{25 \cdot N}{t} = \frac{25 \cdot N}{i_{1000}} = \frac{1.5 \cdot N}{i_{60}}, \text{ in ft/sec,} \quad (3)$$

with the relationship

$$V = 40 \cdot v, \text{ in frames/sec.} \quad (4)$$

With 8 frames in 5 ms, a film velocity of 40 ft/sec results.

8-Mm Film:
$$v = \frac{12.5}{t_1} = \frac{12.5 \cdot N}{t} = \frac{12.5 \cdot N}{i_{1000}} = \frac{0.75 \cdot N}{i_{60}}, \text{ in ft/sec,} \quad (3')$$

with the relationship

$$V = 80 \cdot v, \text{ in frames/sec.} \quad (4')$$

With 8 frames in 5 ms, a film velocity of 20 ft/sec results.

Frame time and film velocity are related values. They always satisfy relationships (2), (3) and (3′). Both values are also used advantageously for special evaluation tasks, such as determining operating time of a machine part, cyclic rate of a mechanism, etc.

What is the *operating time of a machine part,* when the former comprises N frames on the film?

The beginning and ending of the operation have been marked and N frames have been counted for this time interval. First, the frame time, t_1, has to be determined according to (1), by evaluating a short time interval, consisting of a few timing units in the middle of operating time. Then the operating time, t, is:

$$t = N \cdot t_1, \text{ in ms.} \quad (5)$$

For example: With the above frame time of 0.625 ms/frame, an operation comprising 80 frames lasts 50 ms. For a long operating time, the frame time, t_1, may be taken at the beginning and at the end of operation and the average value thereof may be used for calculations.

What is the *cyclic rate* of a gun (or other mechanism) when N frames are counted for the cycle time, t? Using frame time t_1, the cycle time is given by Eq. (5) and the cyclic rate follows:

$$n = \frac{60{,}000}{t} = \frac{60{,}000}{N \cdot t_1}, \text{ in rpm.} \quad (6)$$

For example: With the above frame time of 0.625 ms/frame and 80 frames per cycle, the result is a cyclic rate of 1200 rpm.

What was the approximate *total running time of the film,* T, in seconds?

To answer this question, the average film velocity over the total running time, $\bar{v}$ or $\bar{V}$, should be known. Figure 2 illustrates the acceleration characteristic of film run, that is, the increase of film velocity during film run in the camera. The average film velocity, $\bar{V}$, is somewhat lower than the maximum film velocity near the end of the film run V_{max}. How much lower it is depends on the type of camera and, eventually, on the voltage used. For one type of high-speed motion picture camera the proportion

$$\frac{\bar{V}}{V_{max}} = \frac{\bar{v}}{v_{max}}$$

was found to be approximately 0.8. To have more accurate data available, the acceleration characteristics should be determined for all types of cameras and voltages used. Based on a film length of 100 ft, the total running time then is:

$$T = \frac{100}{\bar{v}} \text{ sec.} \quad (7)$$

When introducing the film velocity in frames/sec:

16-mm film: $$T = \frac{4000}{\bar{V}} \quad (8)$$

8-mm film: $$T = \frac{8000}{\bar{V}} \quad (8')$$

For example: With a maximum film velocity, v_{max} = 70 ft/sec (V_{max} = 2800 frames/sec for a 16-mm film), the average film velocity is approximately 56 ft/sec or 2240 frames/sec, which means a total running time of 1.78 sec.

What is the *average velocity of a machine part*, $\bar{v}^*$, when its travel over a known distance of s inches corresponds to N frames on the film?

First, the corresponding time t, in ms, has to be determined according to equations (1) and (5). Then the average velocity is:

$$\bar{v}^* = 1000 \cdot \frac{s}{t} \text{ in./sec.} \quad (9)$$

or $$\bar{v}^* = 83.33 \cdot \frac{s}{t} \text{ ft/sec.} \quad (9')$$

For example: With s = 4.8 in., and t = 25 ms, the average velocity is $\bar{v}^*$ = 16 ft/sec.

Basic Tasks for Precalculation and Formulae Used

This second group of tasks comprises calculations which must be made prior to taking a picture in order to determine optimum operating conditions for the camera.

1. *Time to Be Recorded*

What is the time of a burst of N′ shots, T′, when fired with a cyclic rate of n rpm?

$$T' = \frac{60 \cdot N'}{n} \text{ sec.} \quad (10)$$

For example: A burst of 25 shots, fired at a cyclic rate of 1200 rpm, lasts 1.25 sec. Since the initial run of the camera does not give sharp pictures due to the low film velocity in the beginning (see Fig. 2), the burst and its recording is started with a certain delay after the beginning of film run by means of an electronic timing device. Assuming that a delay of 0.50 sec is necessary, the total running time of the film, T, has to be at least 1.75 sec in order to cover the whole burst. Therefore, the time to be recorded, T′, prescribes a lower limit for the total running time, T, or, in other words, an upper limit for the maximum film velocity, V_{max}. To select the right maximum film velocity and corresponding voltage, the acceleration characteristic of the camera and some additional data must be given.

2. *Minimum Film Velocity*

What is the minimum film velocity permissible for sharp pictures, v_{min} or V_{min}?

The image of a moving gun part on the film also moves during exposure time of the corresponding frame and brings about a blurred picture (see Fig. 3); therefore, the image travel per frame must be less than a certain limit, when sharp pictures are desired. The factors determining the image travel are:

Maximum velocity of machine part, v:* The faster the machine part is moving, the greater will be the image travel during exposure time. Here, only the projection of the velocity onto a plane

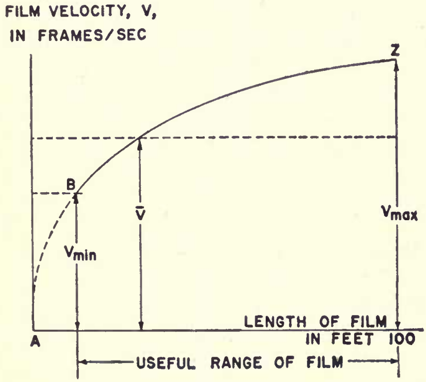


Fig. 2. Acceleration characteristic of film run.

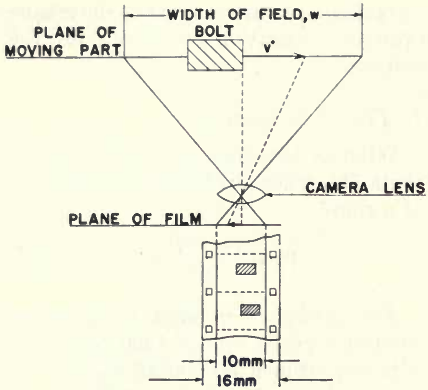


Fig. 3. Relationship between object and image.

through the moving part, parallel to the camera lens, has to be considered.

Reduction of image in camera: This defines the proportions of image to object dimensions (see Fig. 3). It can be expressed in terms of the width of field, w, which is covered by the effective width of the film, the latter being approximately 0.4 in. for the 16-mm film and 0.2 in. for the 8-mm film. The reduction itself then becomes 0.4/w and 0.2/w, respectively.

Exposure time of one frame and film velocity: The image travel per frame changes in proportion to the exposure time, i.e., in the inverse ratio to the film velocity (assuming a constant ratio of exposure time to frame time).

With one type of high-speed motion picture camera the permissible image travel during exposure time, which still guarantees sharp pictures, is 0.002 in. This means approximately 0.010-in. image travel per frame, since the exposure time is about one-fifth of the frame time. The film velocity, therefore, must be greater than a certain lower limit, V_{min}, in order to obtain sharp pictures. This means that the beginning of the film, moving with velocities less than V_{min} during exposure, cannot produce records meeting all requirements.

Based on an image travel of 0.010 in. per frame, the following formulae are obtained for the minimum film velocity (compare with chart for selecting speed given by Eastman Kodak Co.):

16-mm film:

$$v_{min} = 12 \cdot \frac{v^*}{w} \text{ ft/sec} \qquad (11)$$

$$V_{min} = 480 \cdot \frac{v^*}{w} \text{ frames/sec} \qquad (12)$$

8-mm film:

$$v_{min} = 3 \cdot \frac{v^*}{w} \text{ ft/sec} \qquad (11')$$

$$V_{min} = 240 \cdot \frac{v^*}{w} \text{ frames/sec} \qquad (12')$$

For example: When a machine part moving with a maximum velocity $v^* =$ 40 ft/sec has to be photographed on 16-mm film within a field 10 in. wide, only film velocities greater than 48 ft/sec or 1920 frames/sec will guarantee sharp pictures. For 8-mm film, the film velocity must be greater than 12 ft/sec or 960 frames/sec, with the same velocity of machine part and width of field assumed.

3. Conclusion

The correct film velocity to be chosen for recording lies within a range where the lower limit is determined by claiming sharp pictures, while the upper limit is prescribed by the time to be recorded and possibly by the illumination required to obtain a suitable exposure. The acceleration characteristic of film run, illustrated in Fig. 2, should be known for each camera under various operating conditions.

Description of Slide Rule

Since the above formulae involve only multiplications and divisions, a slide rule based on logarithmic scales seems to be the best approach to a mechanical computer.

The slide rule developed consists of three parts, the *body*, the *slide* and the

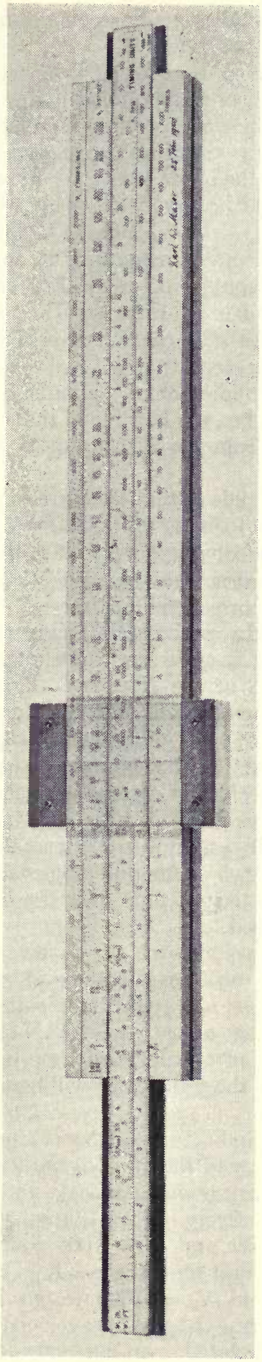


Fig. 4. Model of linear slide rule for analysis of high-speed motion picture films.

indicator, the latter two moving in longitudinal grooves of the slide rule body (see Fig. 4).

The slide rule *body* has three log scales, one below and two above the slide groove.

N-scale: This scale is used for the number of frames or pictures contained in any interval of film with a range from 1 to 1000 frames (additional use for the number of shots in a burst, N′). Index "1" of the scale has an arrow (t_1) for reading of the frame time, t_1, in the t-scale of the slide.

v-scale: This scale is used for the film velocity, v, as well as for the velocity of a moving part, v*, both measured in ft/sec. It has two readings, the lower one from 1 to 1000 ft/sec for 16-mm film only, the upper one with a range from 0.5 to 500 ft/sec for 8-mm film only. These are referred to as upper and lower v-scale.

V-scale: Here the film velocity, V, in frames/sec is shown for both 16-mm and 8-mm film. The range extends from 100 to 20,000 frames/sec.

The *slide* is purposely longer than the body in order to cover a wide range of time. It has five log scales.

t-scale: This scale has a double use, either for time, measured in ms, or for the number of timing units, i_{1000}, when using 1000 timing units/sec. The range extends from 0.1 to 1000 ms.

i_{60}-scale: This scale shows the number of timing units, i_{60}, when using timing frequency of 60/sec, with a range from 1 to 60, i.e., 16.67 ms to 1000 ms. At the 1.5 division of this scale, there is an arrow (v) for reading of the film velocity in the v-scale or V-scale.

n-scale: This scale shows the cyclic rate of an automatic gun or mechanism per minute, with a range from 100 to 10,000 rpm.

Upper w-scale: w indicates the width of field in inches, which is covered by the effective width of film as shown in Fig. 3. The range extends from 1 to 100 in. Arrows (8, v_{min}) and (16, v_{min}) point to

the film velocity, v_{min}, in the corresponding v-scale, or V_{min} in the V-scale.

Lower w-scale: This scale is for the width of field, w, measured in feet, with a range from 0.1 to 2.5 ft, to be used together with the upper w-scale for conversion of inches into feet and vice versa.

The transparent *indicator* has a hairline, perpendicular to the direction of the log scales, for alignment of the corresponding values in various scales.

Use of Slide Rule for Evaluation Tasks

1. Correct Slide Position With Reading of Frame Time and Film Velocity

To find the frame time, t_1, and the film velocity, v or V, in a given part of the film record, the procedure outlined below should be followed.

A part of the film strip, short enough so that the film velocity during film run in the camera can be assumed constant for evaluation purposes, should be considered. Then any time interval within this film part, t, will have a constant proportion to the corresponding number of frames, N, where this proportion is identical with the frame time, t_1, defined previously. For example, when $i_{1000} = 5$ timing units or 5 ms correspond to 8 frames, 10 ms will correspond to 16 frames, and the frame time is 0.625 ms. The following, therefore, applies to the slide rule: When *any* time, t, on the t-scale of the slide is aligned with the corresponding number of frames, N, on the N-scale of the slide rule body, *all* time values, t, will be aligned with the corresponding number of frames, N. Especially, index "1" on the N-scale, indicated by arrow (t_1), will be aligned with the frame time, t_1, on the t-scale. This slide position with the proper alignment of t-scale and N-scale may be called "correct slide position" for the given part of film with constant velocity. For another part of film with a different velocity, another positioning of the slide within the slide rule body will be the correct one. The procedure for determining the correct slide position, therefore, includes readings on the film as well as on the slide rule.

In the given part of *film*, select a small number of timing units, i_{1000} or i_{60}, and count the corresponding number of frames, N, by visual approximation or by means of the frame counter. For example, it will be found when $i_{1000} = 5$ timing units, N = 8 frames. Reading fractions of frames increases the accuracy of computation, especially for a smaller number of frames. The procedure for the *slide rule* is comprised of the following steps:

Move the indicator to the value 8 on the N-scale, i.e., the hairline of the indicator must coincide with value 8 (see Fig. 5).

Move the slide so that the corresponding number of timing units, $i_{1000} = 5$, of the i_{1000}-scale converges with the hairline on the indicator, that is, with N = 8. (When the corresponding time is given in terms of i_{60} timing units, then that value of the i_{60}-scale has to be aligned with N = 8 of the N-scale.) This is now the "correct slide position" for all evaluations of time and velocity within the given part of film assumed to have constant velocity. Corresponding numbers of frames of the N-scale, and times of the t-scale, are in alignment as illustrated in Fig. 5. For different evaluations in this part of film, only the indicator is moved.

Move the indicator to arrow (t_1) (index "1") on the N-scale and read the *frame time*, $t_1 = 0.625$ ms, in the t-scale. (When arrow (t_1) on N-scale falls outside of t-scale, read time, t, at N = 10 and the frame time will be $t_1 = t/10$.)

Move the indicator to arrow (v) inside i_{60}-scale and read the *film velocity* v and V in the corresponding v-scale and V-scale, respectively. For 16-mm film, v = 40 ft/sec and V = 1600 frames/sec. For 8-mm film, the result is v = 20 ft/sec and V = 1600 frames/sec. The frame time, t_1, and film velocity, v, which are related, can be considered

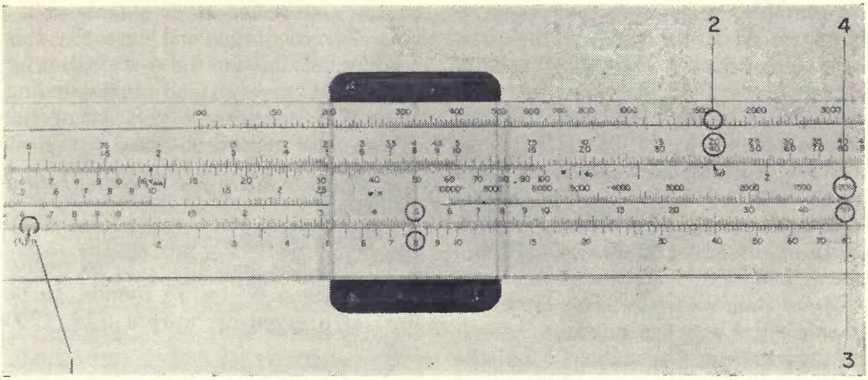


Fig. 5. Setting of slide rule to read.
(1) Frame time (2) Film velocity (3) Operating time (4) Cyclic rate

characteristic values for any such part of film with constant velocity.

2. Operating Time and Cyclic Rate

To find the operating time of a part, t, extending over N frames of the film and the cyclic rate, n, when one gun cycle comprises N frames:

Mark the beginning and end of operating time on the film.

Determine the correct slide position for this part of film according to Paragraph 1 above, by evaluating a time interval in the middle of operating time (or by taking the average of two evaluations, at the beginning and end of operation). The same slide position as in Paragraph 1 above, with frame time of 0.625 ms, may be assumed.

Count the number of frames corresponding to the given operation, N, in the film by visual approximation or by means of a frame counter. For example, N = 80 frames, may be found.

Move indicator to the numeral "80" in N-scale and read *time of operation*, t, in t-scale at the hairline. It will be found that t = 50 ms (compare with Fig. 5).

When this time of operation, t, is identical with the cycle time of the gun, read the corresponding cyclic rate, n = 1200 rpm, in the n-scale with the same indicator position, i.e., above t = 50 or N = 80 (see Fig. 5).

Note: The tasks described for determining frame time, film velocity, operating time and cyclic rate, represent the basic evaluation of a given film by means of the slide rule. All log scales, with exception of the two w-scales and at times the i_{60}-scale, are involved. When several operating times must be evaluated in the same part of film with constant velocity, the slide remains in its correct position, and only the indicator needs to be moved. Therefore, the timesaving value of the slide rule is increased with the number of evaluations to be made within such a film part of constant velocity. In addition to the basic evaluation tasks, listed above, the slide rule can also be used like a standard slide rule, for other evaluations. In these cases, the final slide position no longer means the correct alignment of the N-scale and t-scale, but rather the adjustment of other scales with other meanings. To show this, two examples will be given in the following.

3. Total Running Time of Film (Approximate)

To find the *total running time* of the film, T, when the average film velocity,

for example, $\bar{V}$ = 2240 frames/sec, is given or has been derived from the maximum film velocity, V_{max}, by means of tested values, the slide rule is used for the solution of Eq. (7), (8) or (8′) as follows:

Move indicator to value $\bar{V}$ = 2240 frames/sec in V-scale. The corresponding average film velocity is then read in the v-scale, 56 ft/sec for 16-mm film and 28 ft/sec for 8-mm film.

Move slide so that "100" on the t-scale is in line with the indicator.

Move indicator to index "1" of the corresponding v-scale and read the total running time, T, in seconds at the hairline in the t-scale. T will be 1.78 sec for 16-mm film and 3.56 sec for 8-mm film.

4. *Average Velocity of a Machine Part*

To find the average velocity of a machine part, $\bar{v}^*$, when its travel over s inches corresponds to N frames on the film, *for example,* s = 4.8 in., N = 40 frames:

Determine time of travel, t in ms, according to Paragraph 2 above. In the numerical example (which follows Eq. (9′) above), t = 25 ms.

Move indicator to number "25" on v-scale for 16-mm film.

Move slide until number "4.8" in the upper w-scale coincides with the hairline.

Move indicator to index "1" on v-scale for 16-mm film and read the average velocity, $\bar{v}^*$, in the upper w-scale in in./ms and in the lower w-scale in ft/ms. For the numerical example, this reading falls outside the w-scale, but by reading at v = 10 and corresponding correction, an average velocity of 192 in./sec or 16 ft/sec is obtained.

Use of Slide Rule for Precalculation Tasks

1. *Time to Be Recorded*

To find the gun time, T, to be recorded, when N′ = 25 rounds, to be fired at a given cyclic rate n = 1200 rpm:

Move indicator to arrow (t_1) of N-scale.

Move slide, so that the given cyclic rate, n = 1200, lines up with the indicator.

Read the cycle time of the gun, t = 50 ms, in t-scale above arrow (t_1) of N-scale.

Move indicator to N = 25 in N-scale and read the time of a burst of 25 shots in the t-scale at the indicator. Because this reading falls outside the t-scale, the value 125 is read at N = 2.5 and multiplied by 10, so that a burst time of 1250 ms or 1.25 sec is the answer.

2. *Minimum Film Velocity*

To find the minimum film velocity permissible for sharp pictures, when the maximum velocity of the moving part, v*, and the width of field to be covered by a 16-mm film, are given, *for example,* when v* = 40 ft/sec, and w = 10 in.:

Move indicator to number "40" on lower v-scale for 16-mm film (see Fig. 6).

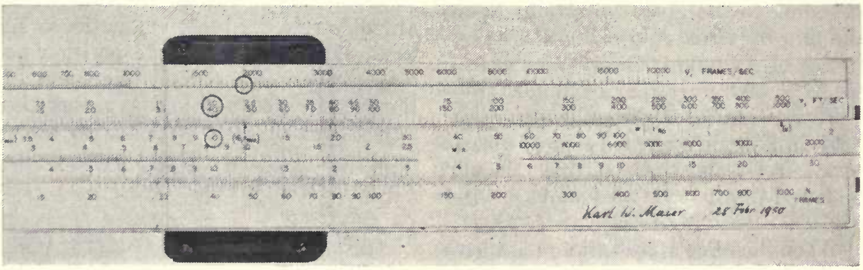


Fig. 6. Setting of slide rule to determine the minimum film velocity required to obtain sharp pictures.

Move slide so that number "10" in upper w-scale (in inches) comes under indicator.

Move indicator to arrow (16, v_{min}) in upper w-scale. The minimum film velocity permissible is then read at the hairline in the lower v-scale or V-scale and will be v_{min} = 48 ft/sec or V_{min} = 1920 frames/sec. For 8-mm film the *upper* v-scale and arrow (8, v_{min}) must be used for reading of both velocities, v^* and v_{min}. The minimum film velocity permissible for the same values as in the above example will be 12 ft/sec or 960 frames/sec.

It should be borne in mind, however, that this calculation is based on a permissible image travel of 0.010 in. per frame, with only 0.002 in. image travel during exposure. For cameras with other image travel during exposure time, the location of the arrows (16, v_{min}) and (8, v_{min}), in the upper w-scale would have to be changed.

Value of Slide Rule

For many of the basic computations which must be made by a motion picture engineer, such as evaluations of given film records as well as precalculations for optimum operating conditions of the camera, the above-described slide rule eliminates all numerical calculations.

Of important advantage in perform-

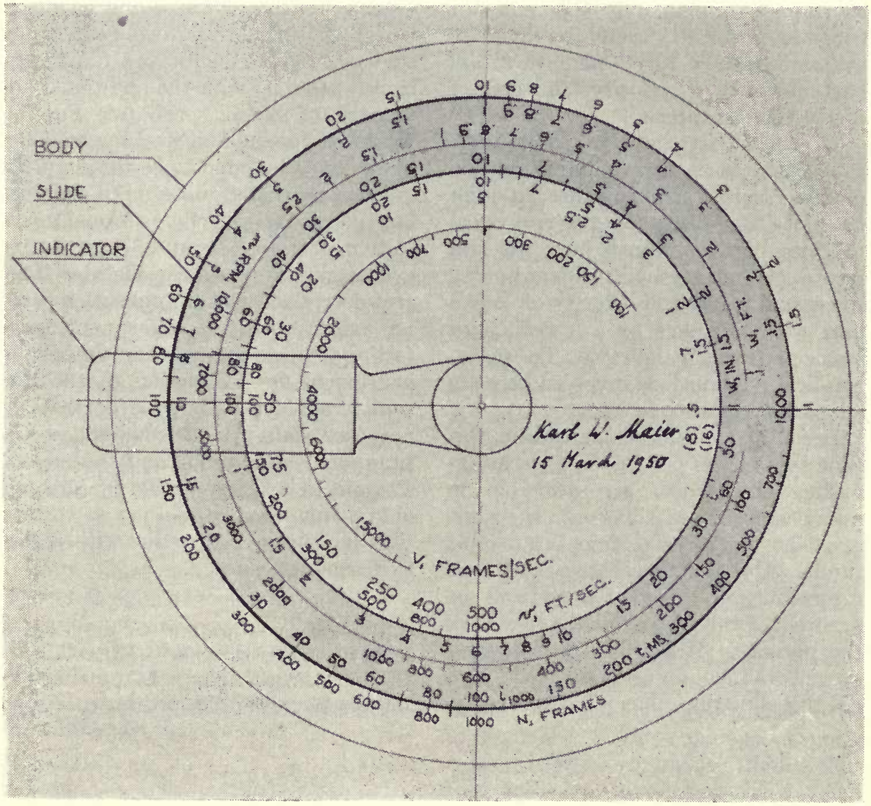


Fig. 7. Model of circular slide rule for analysis of high-speed motion picture films.

ing evaluation tasks by means of a scale is that any length measurements on the film are eliminated. Counting of frames is done simply by visual approximation (for smaller numbers) or by a frame counter (either on the projector or separate), using the frame height as a unit of film length. Measuring of time is done by counting a small number of timing units. In evaluation, the whole film strip is divided into parts of such length that the corresponding film velocity can be considered constant. Due to the constant proportion between length and time within such a short part of film, a definite position of the slide with regard to the slide rule body is prescribed. For evaluations within such a short part of film, only the indicator needs to be moved; therefore, the more evaluations have to be made in a film part of constant velocity, the greater will be this advantage.

It is felt that there are other basic calculation tasks in evaluating motion picture records. For instance, in order to plot time-displacement curves of machine parts, obtained from the film record, a rapid method for determining the actual travel and velocity of such a part with reference to a given point seems particularly desirable. The mathematical relationships involved here are adaptable to slide rule work.

Because of its timesaving feature, this slide rule makes possible long series investigations, which are desirable in many cases, inasmuch as only the average value of a series represents a reliable result. Due to its mechanical function, errors in computing are reduced and the accuracy obtained is sufficient to answer the purpose. It is believed that, after special training, an assistant could handle this slide rule, thus relieving the engineer from time-consuming elementary calculations.

Another use for the slide rule is in calculating optimum operating conditions of the camera prior to taking a picture. It is believed that the present value of the slide rule could be still further increased by adding a scale for the total running time, if more data, regarding acceleration characteristics of different cameras under different voltages, as functions of film travel and time, could be provided. These acceleration characteristics could be obtained by evaluations of film records.

Modification of the present model can be readily effected to include other types of film (35-mm) and timing according to the needs of the engineer. Instead of a linear arrangement of log scales, as shown, a circular arrangement is also possible, with the additional advantage of saving space (see Fig. 7). However, for the first working model, a linear one was found to be the simplest.

Up to the present time, motion picture records are used chiefly as a qualitative testing method, because quantitative evaluations consume considerable time. However, their field of application could be extended to include quantitative testing also, if a suitable and timesaving instrument for evaluation of the film were available. It is believed that the proposed slide rule greatly reduces the time for computations and that it will also aid in making motion picture records a quantitative method of testing, thus increasing their value with regard to mechanics research.

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Use of Image Phototube as a High-Speed Camera Shutter

By Alsede W. Hogan

The image phototube is destined to become an important means of taking good quality high-speed photographs. Its worth has already been proved in several fields. It has a much greater light efficiency than the Kerr Cell. A light *gain* is possible. The angle of view, in contrast to the Kerr Cell, is governed entirely by the lens system used. Relative applications of the device include ultra-high-speed stroboscopes and a versatile color television system. Application of the shutter to very fast multi-frame photography is discussed.

The image phototube, or image converter tube as it is often called, first came into prominence during World War II because of its use in the "Snooperscope" and "Sniperscope," which enabled our troops to see the enemy in the dark. It has recently been used in lieu of a shutter in ultra-high-speed photography and, as such, is an important addition to the photographic art. The tube has allied pulsed applications in stroboscopy and television. It may also become more popular in its continuous current applications as an image converter in such fields as spectrometry and photography.

In its operation as a shutter an image is focused upon the photocathode by a conventional lens system. The tube is then energized by a high-voltage pulse which is equal in duration to the exposure time desired. The applied voltage will cause the electrons leaving the photocathode to impinge upon the fluorescent screen and thereby reproduce the image as it appeared on the photocathode. The persistence of the screen will provide an output image of longer duration than the electrical pulse but will not change the effective exposure time so far as the object itself is concerned, because additional electrons do not arrive after the pulse is ended. This persistence is beneficial in most applications because it allows more time for the film exposure.

Photographic Applications

Considerable work has been done in the United States and England on single-frame photography. Dr. Courtney-Pratt of Cambridge University, England, has published some important work in multi-frame and streak photography.[2,3] He has emphasized the photography of self-luminous phenomena. Multiple frames are obtained in this instance by deflecting a small fluorescent image onto various parts of a relatively large screen and exposing the entire area to a single photographic

Presented on May 2, 1951, at the Society's Convention in New York, N.Y., by Alsede W. Hogan, Missiles Division, Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

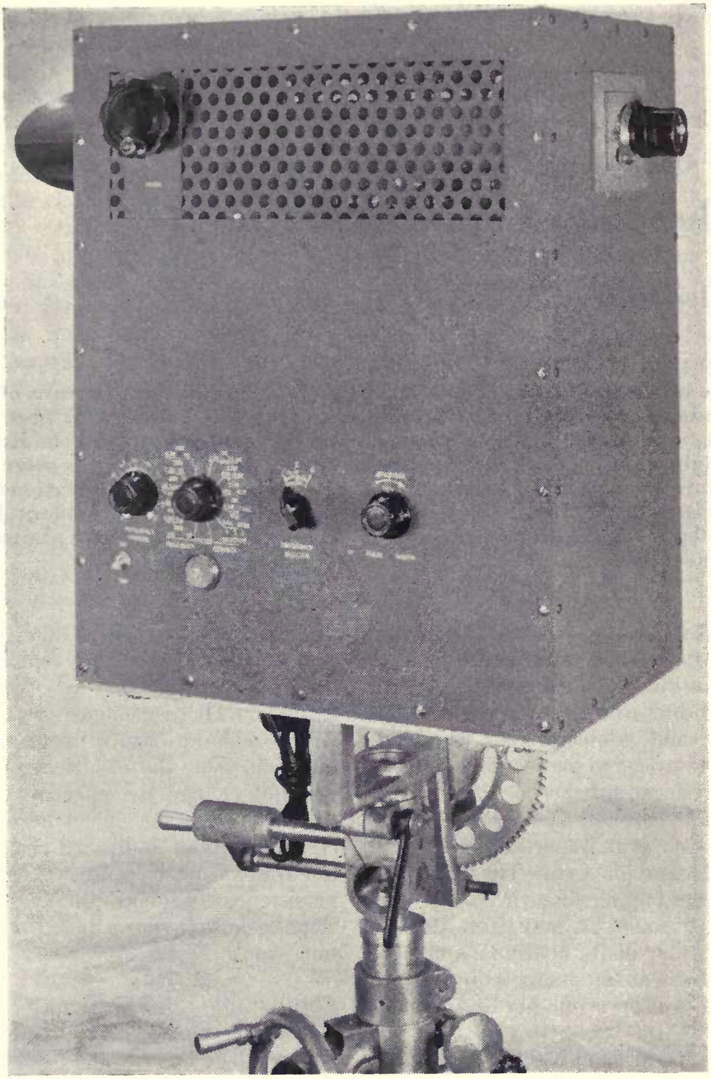

Fig. 1. NOL ultra-high-speed stroboscope.

frame. It is believed that a few frames of the object can be obtained in this manner at a rate in the order of millions per second. It is important to note that the quality of the pictures will not suffer because of the very high frame rate.

Application to conventional types of motion picture photography probably can be easily accomplished. For high frame rates it will be necessary to develop tubes having phosphors with fast decay. P1 and P5 phosphors fall to about 10% of their original brightness in 14,000 and 18 μsec, respectively. Type P15 is faster than either of these. These figures indicate that sufficiently

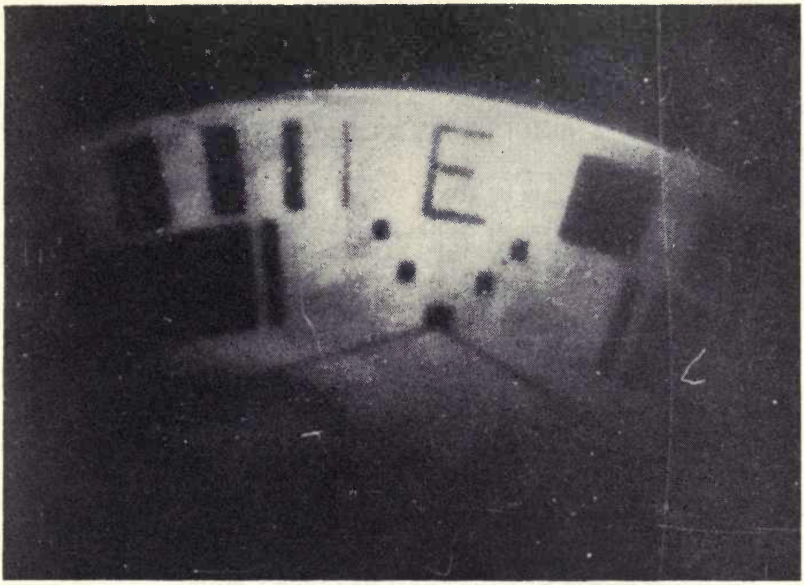

Fig. 2. Revolving wheel, 2-microsecond exposure.

fast phorphors are presently available; however, some difficulties may arise in their application. For example, it is necessary to have some screens backed with aluminum in order to prevent poisoning by the photocathode material. Most of the tubes available now have P1 (green) screens. It is very likely that the limit upon the frame rate will be determined by the speed with which the film can be moved.

The tube itself can be pulsed much faster than is ever likely to be required for motion pictures, as is evidenced by the NOL (Naval Ordnance Laboratory) stroboscope which has a maximum repetition rate of 300 kc. This value could be increased in the order of megacycles if required. (See Fig. 1.)

Single photographs, utilizing light reflected from the object, have been obtained at NOL with an exposure time of 2 μsec (see Fig. 2). A flashtube having a 2-μsec duration has been photographed at various stages of ionization with ½-μsec exposures. The NOL Explosives Research Dept. has obtained good photographs of explosions with exposure times in the order of 0.03 μsec.

Allied Applications

Stroboscopes using the image phototube can have a much greater repetition rate and a much shorter "on" time than ordinary types. The power consumed by the NOL stroboscope is about 150 watts and does not vary appreciably for repetition rates between 50 c and 300 kc. It can be operated continuously. Such stroboscopes will find important use in ultrasonics, flame studies, and some types of machinery design where the use of flashing lights is impractical.

A color television system using image phototubes is being privately developed by the writer. It is a completely electronic system whereby color intelligence can be imparted to or taken from presently existing systems such as the CBS field-sequential system, the CTI line-sequential system and the RCA dot-

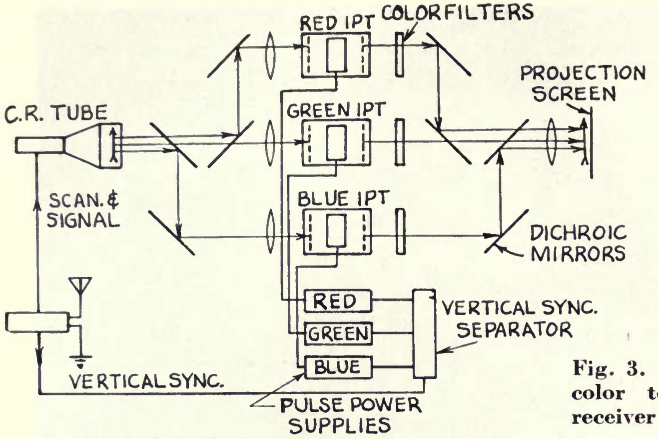

Fig. 3. Image phototube color television system, receiver block diagram.

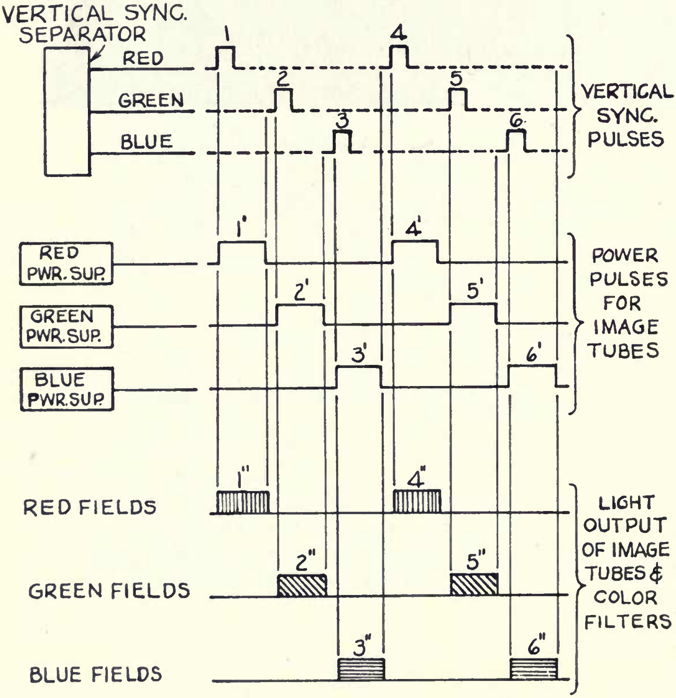

Fig. 4. Pulse sequence for application of image phototube to reception of CBS transmissions. One complete frame is shown.

sequential system. The CBS system will be considered here very briefly. The image phototube system has advantages and disadvantages, but where color television is concerned, any attempt to prove which is superior would be useless as is evidenced by the clash between proponents of various systems. The image phototube system may be used at the transmitting and/or receiving stations. As shown in Fig. 3, the system is all electronic and makes use of

three image phototubes at the receiver, in addition to a single conventional cathode-ray tube of the scanning type. The video signal, which is amplitude modulated in accordance with the primary color light intensities reflected from the object being televised, is applied to the scanning cathode-ray tube. The fluorescent screen of this tube will normally have a white phosphor, although its color characteristic is not critical because the relative color outputs of the image phototubes can be adjusted to the proper levels. The image produced on this tube as a result of conventional scanning is split into three parts by a suitable optical system which is not necessarily color selective. Thus the image on the scanning tube is continuously present on the photocathodes of the three image phototubes. Each of these tubes has a phosphor corresponding to one of the primary colors, or, in lieu of this characteristic, each tube may be equipped with an output color filter corresponding to one of the primary colors. In the latter case, the phosphors would preferably be white. By pulsing the image tubes in a predetermined sequence, as at the transmitter, primary color images arrive at the projection screen and are superimposed upon one another by means of an optical system between the tubes and the projection screen. The superimposition of the primary color images at a rapid rate provides the viewer with a full color impression of the object being televised at the transmitter. The image sequence is presented in Fig. 4.

Tubes

At least three types of image phototubes have been used for photographic purposes. The one easiest to obtain but least suitable for general work of this nature is a British type marked CV148 which is available on the surplus market. This tube has fairly good resolution but will break down on the high voltages required for photographs utilizing reflected light. As is the case with most tubes, the applied voltage can be increased as the pulse width is decreased. Good pictures may be obtained of powder explosions with a pulse voltage between 8000 and 12000 volts and a pulse length of ½ μsec.

The 1P25A has fairly good characteristics except that the fluorescent screen is too small to provide adequate picture detail for large objects. This is the tube used in the American Snooperscope and Sniperscope.

The Mullard type ME1201 has been developed especially for such purposes. The large fluorescent screen should provide very good detail when used in its entirety for single frames. It is also suitable for deflecting smaller images to obtain separate frames at very fast rates.

Data on the last two tubes follow (data for the ME1201 are tentative):

	1P25	*ME1201*
Screen diameter	⅞ in.	4½ in.
Photocathode diameter	1¼ in.	1 in. (effective)
Length	4 7/16 in.	9 in.
Spectral response	Infrared	Infrared or daylight
Screen fluorescence	Green	Green
Maximum anode volts (continuous)	4500*	6000
Focus	Electrostatic	Electromagnetic
Resolution	110 line/cm	200 line/cm
Infrared conversion factor	0.22 min.	—
Sensitivity (2700 K color temperature)	—	Daylight cathode: 20 μa/L Infrared cathode: 15 μa/L

* About 12 kv for 2-μsec pulse

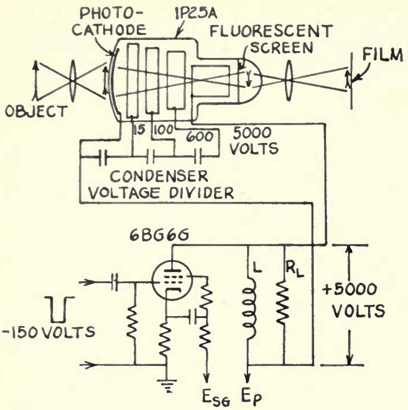

Fig. 5. High-voltage pulse circuit.

Pulse Power Supplies

In the early experiments at NOL the power pulses were generated by discharging a pulse-forming network through a hydrogen thyratron. Later a radar-pulse modulator was used. These methods were satisfactory for single photographs and stroboscopic applications having low repetition rates; however, they involve an extravagant waste of power at high rates because of the low-impedance output characteristic of such devices. To overcome this difficulty, a circuit was designed which is similar to television "fly-back" power supplies. As shown in Fig. 5, this circuit utilizes the energy stored in the magnetic field of an inductance.

In operation, the 6BG6G normally conducts about 100 ma. When it is desired to pulse the image tube, a negative pulse is applied to the grid of the 6BG6G causing its plate current to cut off, forcing the inductance L to discharge through the resistor R_L which consists of several resistors in series to total about 50,000 ohms. The inductance is sufficiently large to maintain a current of approximately 100 ma, through R_L, for the duration of the short negative pulses on the control grid. This current generates a pulse, across R_L, of about 5000 volts, which is a good operating value for repetitively pulsing the 1P25A.

The output pulse would ideally have the same duration and shape as the grid pulse, but this is difficult to obtain on account of the distributed capacitance of the inductance. Pulses in the order of 30 μsec are reproduced fairly well, but pulses in the order of 4 μsec are triangular in shape regardless of the grid input waveform. The pulse time would be most efficiently used if the pulses were square topped at a value of 5000 volts or more. However, for a great many applications, such efficiency is not required. If the pulse is not square the image tube must be well shielded from stray magnetic fields. A slow rising or falling pulse in the presence of a magnetic field results in a movement of the image which makes it appear out of focus on the developed film.

In using high-impedance power supplies, such as the one above, it is essential that the internal capacitance of the image tube electrodes be padded externally to give a proper distribution of voltages; otherwise defocusing will result, i.e., the high-frequency components of each pulse must be taken into consideration. If it is not required that the instrument work on continuous current, for constant viewing, a resistor-type divider will not be required and the padding condensers can be relied on to function as a voltage divider, as shown in the schematic diagram.

Conclusion

It is apparent that the development of the image phototube system has been held up for several years as a result of the absence of suitable tubes. Robert T. Bayne applied for a patent on the basic system in 1943, and it was issued in 1947. Since that time, several persons, including the writer, have independently developed the idea. A growing need for such devices has been responsible for the recent developments.

References

1. Robert T. Bayne, "Stroboscope," U.S. Patent No. 2,421,182 (May 27, 1947).
2. J. S. Courtney-Pratt, "A new method for the photographic study of fast transient phenomena," *Research*, vol. 2, no. 6, pp. 287–294, June 1949.
3. J. S. Courtney-Pratt, "A new photographic method for studying fast transient phenomena," *Proc. Roy. Soc.*, Nov. 1950.
4. A. W. Hogan, "Use of image converter tube for high-speed shutter action," *Proc. I.R.E.*, vol. 39, pp. 268–270, Mar. 1951.
5. H. A. Prime and R. C. Turnock, "An iconoscope electro-optical shutter for high-speed photography," *Proc. Inst. Elec. Eng.*, vol. 97, pt. 2, pp. 793–796, Dec. 1950.
6. V. K. Zworykin and E. G. Ramberg, *Photoelectricity and Its Application*, Wiley & Sons, New York, 1949.

Discussion

Emmett Salzberg: I would like to know whether any work has been done on taking normal speed pictures of the screen of a phototube.

Mr. Hogan: There has been some indirect work on that. The limitation on taking motion pictures with these tubes will normally be the decay time of the screens. We now have screens, such as the P5, that will decay to about 10% brilliance in 18 microseconds. This will allow a frame rate of 50,000 per second. The P15 screen has a still faster decay—which puts the limitation of the device on how fast the film can be moved.

Mr. Salzberg: I was mainly interested in normal speed motion pictures.

Mr. Hogan: It should work very well for that. In many instrumentation problems, you will find a great advantage in the fact that it gives ease in synchronization. For example, several cameras, photographing different portions of an experiment, can be *easily* synchronized within a fraction of a microsecond.

Mr. Salzberg: Can you tell us the limiting factors affecting the resolution available from the image converter tube?

Mr. Hogan: Several experts that I have discussed the matter with gave different opinions, based perhaps on different points of view. I have concluded that the electron lens represents the greatest problem and the quality of the fluorescent screen comes next. The photocathode, if any good at all, seems to be better than the rest of the tube.

Kenneth Shaftan: Did Dr. Courtney-Pratt use a German tube and did he get better resolution, for example, than the 1P25A samples shown?

Mr. Hogan: I do not know how well he did with the German tube. He later went to the ME1201 which is supposedly much better; it is certainly better than the 1P-25A that I used.

The New Visual Idiom

By Nat Sobel

One of the most important components of good motion picture production as it exists today is the utilization of special effects and their proper planning. To accomplish the purpose of the advertiser, producer or exhibitor, necessary optical stresses must be carefully planned in television or motion picture work. To that end, we have attempted to set forth reasons why certain effects are used in various ways. The following statements should suggest rather than set the rule for what we think is proper according to the experience which the writer has had.

How many of us ever withdraw from our daily preoccupations long enough to view this art and science of motion pictures and television in a general and objective light?

I have to confess my own shortcomings in this for, after a quarter of a century in film production, much of it in the jungles of negatives and positives, and in the press of everyday technical problems and deadlines, somehow I seem to have missed seeing the picture on account of the footage. And so I shall attempt to assay my first love, my friend and foe alike of many years—the optical or special effect. Perhaps a review of opticals as we know them today will bring us some understanding of why they are now universally accepted as a mature medium of visual communication.

What a vexing problem the optical effect can often be. Yet so firmly is it established in modern production, so expanded, so refined, that I'm sure we can think of it, without qualification, as a new visual idiom.

Classification

This new idiom may be classified into four specific categories: the fade, the dissolve, the wipe, and what is known by that rather nebulous and somewhat catchall term, the montage.

This new idiom provides coherence and continuity to a film story. It opens and closes a sequence, it punctuates the narrative, it permits a graceful transition from sequence to sequence, even from scene to scene.

The Visual Idiom

The idiom, as associated with language, is the product of natural growth. It originates to supplant an existing form, or to fill a need. And gradually, because of its convenience, its effectiveness, its superiority, the new form gains broadened usage until it is fully integrated and accepted as part of the language.

Presented in May 1947 before the Atlantic Coast Section meeting by Nat Sobel, Cineffects, Inc., 115 W. 45th St., New York 19, N.Y.

Such has been the history of the optical effect. The dissolve, for example, since its invention by the French cinema pioneer, George Melies, has risen from a singular display of genius to an integral pattern woven into the fabric of every worth-while film production. And, similarly, since the days of D. W. Griffith and the fabulous "Billy" Bitzer, it has been standard practice to begin a film with a fade-in and end it with a fade-out. We do this with an authority equal to the one that tells us to begin a sentence with a capital letter and to end it with a period.

Not too many years ago opticals were regarded as anything but an accepted idiom. They were viewed more or less as a spectacular vernacular. And yet we have only to analyze one of today's professional films to realize how thoroughly opticals have been integrated into the language of the cinema and of television, particularly in the commercials, where opticals are now a mainstay.

Today it is the rule—not the exception—that every film designed to alert and hold the attention of an audience must be laced together with intelligently planned and professionally rendered special effects or opticals. While the average viewer is rarely conscious of the actual techniques, he nevertheless feels their presence—or absence—without identifying them.

The Fade (Fig. 1)

The grandaddy of all optical effects is, presumably, the fade. In essence, it is a device used to represent a pause in the pictorial flow of the narrative. The fade means either "cessation of action" or "inauguration of action." Properly used, the fade is to a screen play what the curtain is to the theater. The fade-in raises the curtain, the fade-out lowers it. The fade supplies intrasequence transition.

Technically, the best fade is the most even fade. There are two ways to execute fades. One is to use a gradual reduction or increase of light, controlled by a rheostat. The other is accomplished by closing or opening the camera shutter from 0° to 170°. Although both methods are effective, our personal preference is the latter. Especially is this true in shooting color, since light controlled by resistance tends to affect the color temperature of the light source, resulting in a not too faithful reproduction of the original.

The Dissolve (Fig. 1)

The dissolve is a device that effects transition *within* the framework of a sequence, or *between* sequences, when there is to be no pause in the flow of the film.

For instance, suppose we want to show the progress of a young chap from the time he is inducted into the army until the time he goes into battle. We have, let us say, scenes of our protagonist enlisting, being examined, receiving his uniform, in training, embarking, landing, marching to the front, and finally in battle. Assuming that none of these scenes are ends in themselves, we could link them together with dissolves for transitional purposes and thus maintain a definite and uninterrupted pace. The battle scene, on the other hand, would probably be an end in itself and so we would end it with a fade.

The dissolve has been called—and with ample reason—the most significant of all cinematic and televisual discoveries. It has myriad uses, many of them basic to the production of a convincing picture. Its extreme value is worthy of illustration by another hypothesis.

Let's assume we have a man—we'll call him "Lefty"—approaching a building and that we wish to move him inside and show him at work robbing a safe. Suppose there were no such thing as a dissolve. We would have two alternatives. One, we might expend the time and footage to bring Lefty into the building, up the elevator, along the corridor and into an office. The alternative

Fade *Dissolve* *Wipe*

Figure 1

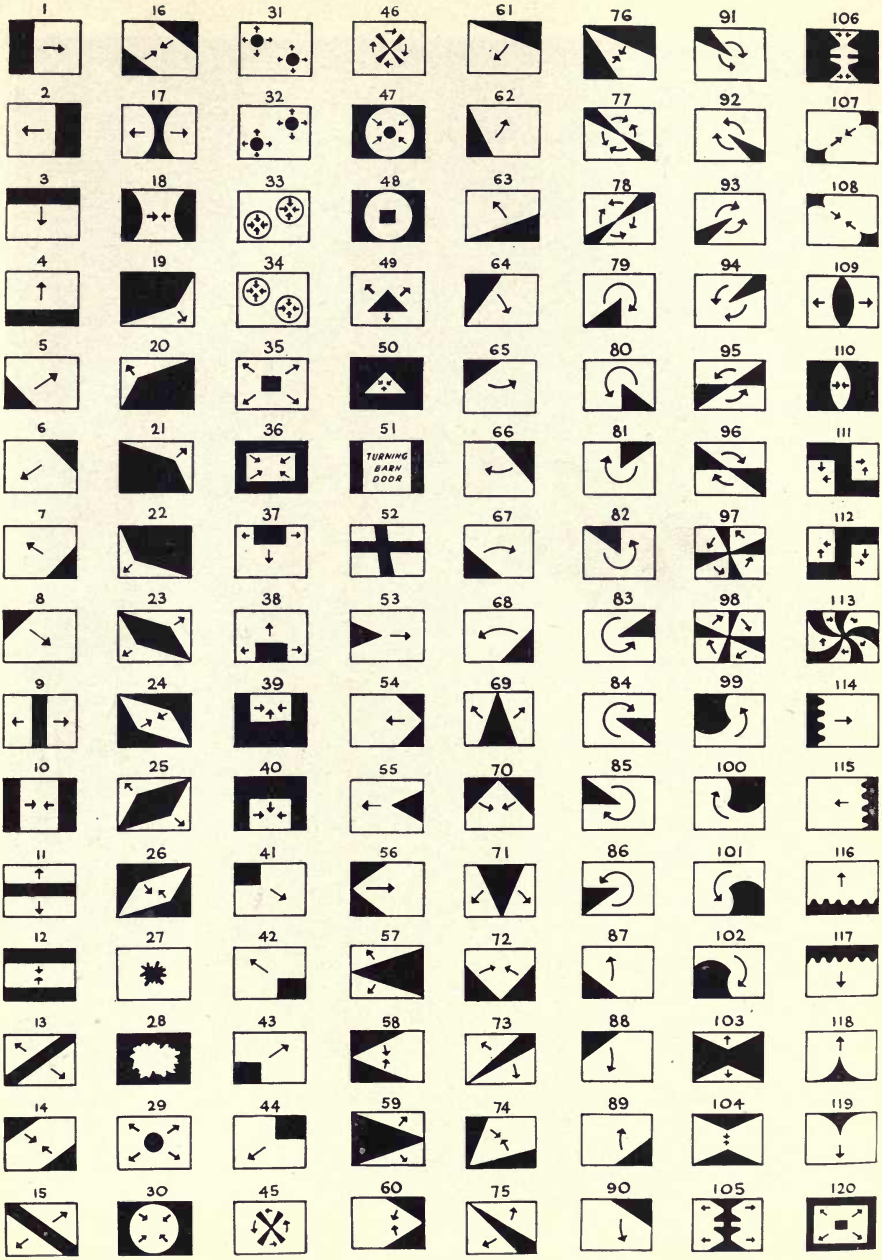

Fig. 2. Graphic outline of a variety of optical wipe effects, reproduced from a chart made by Cineffects, Inc.

96 79 6

Fig. 3. Trailer and television wipes.

9 29 1

Fig. 4. Feature, or production, wipes.

would be to straight-cut from exterior to interior, and thereby give the audience the impression that they are watching a jet-propelled Superman.

Of course, the proper way to make the transition is to use the dissolve.

A dissolve is nothing more than a combination of a fade-out and a fade-in. The measure of a good dissolve is the equilibrium of density, and of highlight and shadow, between the two shots used. Experience teaches us that the best dissolves are achieved when we do not use the same length of shot on both sides of the optical center. Flush dissolves, which call for the opening and closing of the shutter to a full mathematical 170° during the time of the effect, are practical only when the dissolve is made between two shots that have identical backgrounds.

The Wipe (Fig. 1)

Figure 2 shows graphically the many types of wipes which are generally used. The wipes illustrated in Figs. 3 and 4 are correlated by number with those on the chart (Fig. 2).

The wipe is an optical device used to represent simultaneous action.

Here we have Michael playing golf, and we wipe to a scene of his wife Jacqueline at a tea party. By this action we infer, visually, that Jacqueline is having tea while Michael is playing golf. The dissolve usually infers succeeding action, whereas the wipe infers contemporary action.

The psychology behind the use of many wipes in trailers and television spots is apparent when we consider that the purpose is to show that there are distinct advantages in seeing the film or buying the product being advertised, because of the number of exciting and interesting situations happening in the film or a number of superiorities in the advertised product, situations or advantages which the patron can't afford to miss. The wipe is used to heighten this impression, to plant the idea that all these wonderful things are simply bursting through the sprocket holes, occurring almost simultaneously.

Wipes are executed by means of film or metal mattes. In our optical department we have developed more than 120 types, each one of which is capable of producing an unusual and individual type of effect. Trailers and television spots usually employ the more bizarre wipes, usually with sharp edges, which are calculated to give impact. In features, however, the principal types used are soft, the common types being right to left, left to right, diagonal and vertical. (See Figs. 3 and 4.)

The Montage

The montage offers the most fascinating possibilities in this new visual idiom. And, although superimposition, split screens and similar techniques have enlivened some pictures which would otherwise have creaked through, montages themselves have often mounted pictures to such powerful climaxes that no ordinary narrative could hope to keep abreast of them.

An accurate definition of a montage is difficult. It has come to mean almost everything from superimposed scenes, double exposures of various kinds, and split screens, to a series of short shots dissolving into one another.

The most fascinating aspect of the montage is the ability to burst the bonds of time and space (Figs. 5A and 5B), and even reason, and still to remain entirely credible. When we see the picture of a bullet superimposed over a shot of a turning globe which may even be combined with that of a ship at sea with the waves breaking over its bow, we do not pause to question this violation of time and space. The appeal of the montage is wholly emotional. We feel that the montage—this magnificent, yet almost entirely unexploited device—offers to producers an effective transition and to television advertisers a brand new cinematic dimension. (See Figs. 5A and 5B.)

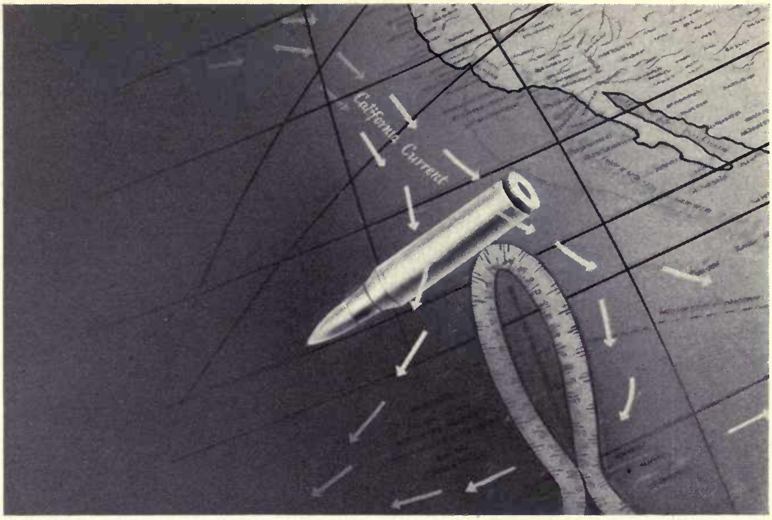

Figure 5A

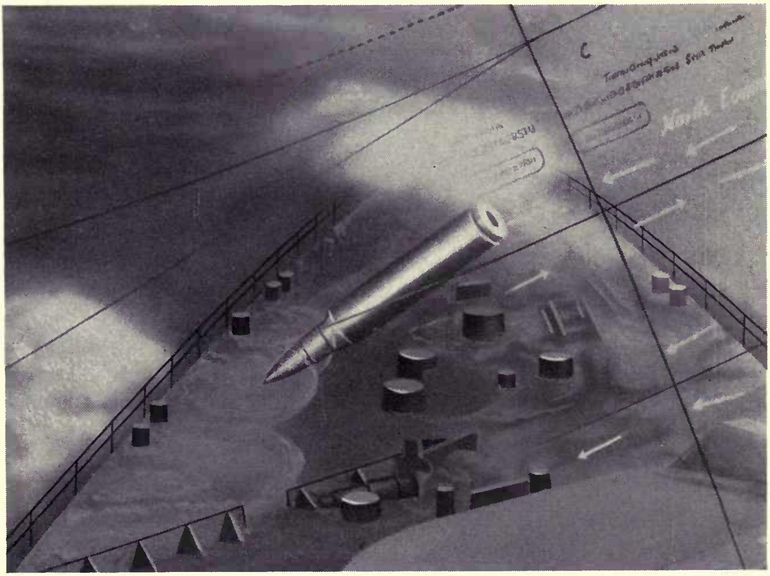

Figure 5B

Time-lapse montage illustrating superimposition over split screen.

Planning

It is our belief that the motion picture in television is an accepted medium of expression and that a major reason for its acceptance is the new visual idiom. The maturity of the optical techniques brings an additional element of responsibility, particularly with respect to the care and forethought the producer should put into planning them. The time for planning is *before* photography is started.

A typical instance where proper forethought spelled success in the end occurred in a production where the script called for bullets emerging from a machine gun in action. Even tracer bullets, we know, are barely visible in daytime, so that a special technique had to be worked out in advance of shooting.

We worked out the following procedure: The machine gun was anchored and photographed in action during the daytime. Then, the same gun was photographed in action at night, using tracer bullets which were visible as they emerged from the barrel in the darkness.

It was possible then to literally matte out the superfluous exposure in the second shot, and superimpose it over the daylight shot, at the same time dodging out the superfluous exposure of the sky in the first take. The net result was visible bullets emerging from the machine gun (Fig. 6).

Advanced planning cannot be overemphasized. There are good shots for wipes and dissolves, and bad shots. The best dissolves are made in the mind, not in the camera. The day is past when a producer gathers an assortment of shots and bundles them off for "suitable" opticals.

Titles

The average movie or television fan has come to expect that a picture will open with smart titles over an interesting background. He senses that the main title fades in, that credit titles dissolve into each other, and that an optical is used to mark divisions between titles and picture.

The modern producer devotes considerable time and thought to the creation of striking and symbolic main titles—the pictorial overture. They are calculated to arrest the eye, awaken interest and set the mood for the film that follows.

Innovations in the field of title work call for ingenuity in the title department. Let me sketch for you the techniques we used for a recent production. This type of title treatment is in common usage not only in motion pictures, but also in television commercials.

Our storyboard calls for the superimposition of white titles, with black shadows, over a live-action scene. The scene shows black buildings on a snow-covered landscape. The technical problem is to retain white titles against the snow. (See Fig. 7).

In this instance, since the live action is an inherent part of the desired effect, our problem is more complicated.

First, we render our lettering in white on a glass panel, drawing in the offset black shadows on the opposite side of the glass to give the illusion of depth.

We begin photography by bipacking a fine grain of the live-action shot, with negative stock. Our camera photographs the black shadows of the lettering acting as a matte over a white card, thereby resulting in a dupe negative (undeveloped, of course), of the scene with letters.

Next, we rewind the negative stock to starting mark previously made on the raw stock. We then photograph the lettering over a black card after first removing the fine grain. Now the shadow of the lettering is lost in the dark background and the white lettering itself is heavily exposed over the previously duped live-action scene. Thus, we arrive at the desired result, a duplicate negative of the live action over which is superimposed, in perfect regis-

Fig. 6. Composite matte shot.

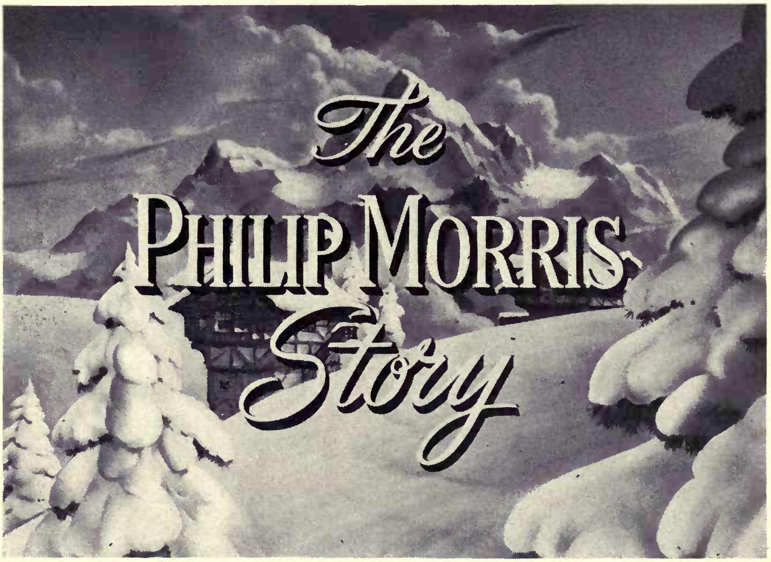

Fig. 7. Title, illustrating enhancement of white letters over predominantly white background.

tration, the white title with the black shadow (Fig. 7).

A further complication arises if the titles must move, as, for instance, when there is a considerable amount of copy. Only a pan title serves the purpose. In such a case, the previously described operations take place, but the letters and shadows are moved according to minute calibrations, accurately determined, depending upon the reading time necessary for comprehension. A photographic technique is utilized, to which we refer as "stop-motion," (frame by frame exposure), a necessity because of the extreme accuracy required in matching the position of both exposures of the lettering and shadows in action.

Television

Whatever importance you are inclined to attach to our new visual idiom with respect to motion picture productions, should be doubled for television.

We have found in our organization that we should never begin shooting without a prior conference of department heads. Nine times out of ten these discussions turn into involved debates on optical treatments. We find that when the various components—live action, animation, stop-motion, etc.—*are preplanned,* they come together in a smooth, optical integration of the segments, a composite of an effective, workable commercial.

We find, too, that optical effects are no longer confined to the optical bench. On our animation stands, in particular, much hard thinking on the part of the camera supervisors—plus the unusual gadgets we have developed—makes possible many of the special effects so necessary for television spots.

Films employing these effects enjoy a psychological advantage. From the very first frame the audience senses that it is in for a treat, one that comes only from a highly original job, professionally executed.

Acknowledgments

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Special Techniques in Magnetic Recording for Motion Picture Production

By George Lewin

Several modifications in standard magnetic recording systems which provide greatly improved operating efficiency as well as economies in time and materials are described. These include facilities for: (1) stopping and reversing recorder and projector without losing synchronism, and (2) changing over from Record to Playback, or vice versa, silently, while running. These facilities make it possible to correct errors in narration and re-recording jobs without need for rethreading, splicing or blooping the film. Also described is a new method for domestic and foreign lip-synchronous production which makes use of 35-mm magnetic loops.

The Signal Corps Photographic Center was one of the earliest, if not the earliest, user of magnetic recording for motion picture production work. As soon as the availability of 35-mm magnetically coated film was announced it was recognized that here was a new medium which offered possibilities for effecting tremendous economies in the use of photographic film and its attendant processing costs. Steps were immediately taken to design an attachment for existing optical-type film reproducers, to permit the recording and reproduction of magnetic sound tracks. An RCA Fantasound type of film reproducer was fitted with an erase and record head and was in successful use for recording and reproducing narration tracks as early as 1947 (Fig. 1).

It was quickly realized, because of the scarcity of magnetic film stock at that time, that it would be undesirable to cut up the film for the purpose of editing out errors in the narration, thereby losing one of the main advantages of magnetic recording, namely, the ability to use the stock over and over again and thus reduce its actual cost to the vanishing point.

Standard Procedure in Photographic Recording.

Before the advent of magnetic recording, the normal practice in recording narration tracks for motion pictures was to use regular photographic film, and to record "wild," that is, without picture, and make numerous retakes to obtain the desired inflections and timing. The negative would then be developed and printed, and the print sent to the cutting room where considerable editing would have to be done to cut out errors, splice

Presented as the first of two papers on May 4, 1951, at the Society's Convention at the Hotel Statler, New York, By George Lewin, Chief Recording Engineer, Sound Branch, Signal Corps Photographic Center, New York.

in the corrections, and juggle sentences back and forth to obtain the desired timing. In spite of the high cost of this procedure, the final result often left much to be desired because of the noise introduced by excessive handling of the film, the splices, and the inherent noise of film processing.

Magnetic recording appeared to offer the possibility of eliminating most of these problems. Our reasoning was somewhat along the following lines:

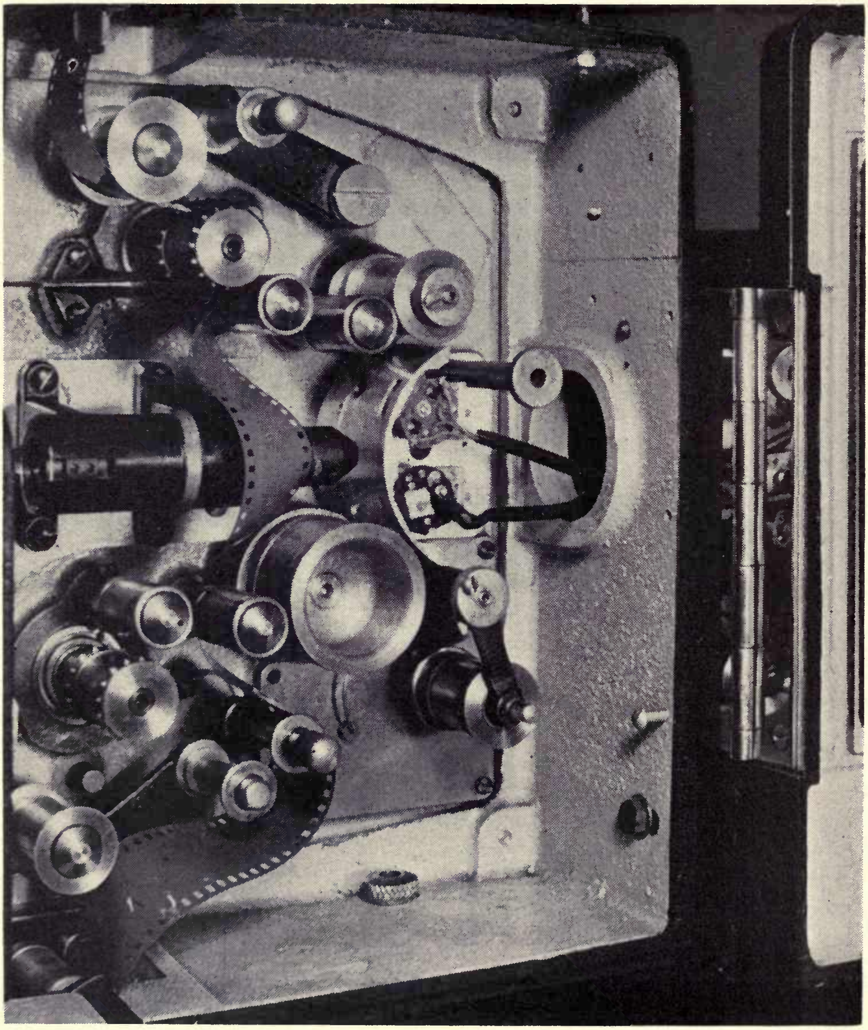


Fig. 1. Signal Corps Photographic Center modification of RCA Fantasound Reproducer showing magnetic erase and record heads set into curved aperture plate.

Requirements for Synchronous Narration of Magnetic Film

Suppose we had a medium which would allow us to stop both picture and sound track if the narrator made an error, back up ahead of the point at which the error was made, then run forward again, correcting the error and proceed onward, all without losing synchronism, and without leaving any telltale bloops or noises. If we could do all these things, we would really have a major improvement in production technique. Not only would we have a perfect narration track ready for immediate use, but we would also have eliminated completely the use of photographic film, its processing, editing, and the attendant cost and time. The fulfillment of all these requirements obviously presented a number of formidable problems, but these were all solved in due course, as improved projection and recording equipment became available and were modified to meet our special requirements.

Modifications for Reverse Drive

The projector (Fig. 2) was equipped with an additional belt coupled to the upper feed reel, which acted as a take-up when the motor was reversed. The intermittent movement of the Century projector head is capable of being driven in reverse with no particular precaution other than reducing the tension of the pressure plate.

The Westrex 1231 type of magnetic recorder (Fig. 3) was fitted with a special take-up and feed assembly which was designed especially for us by Westrex, and which runs equally well in either direction. Figure 4 shows a front view of this recorder.

The 3-phase interlock type of motor distributor system in use at the Signal Corps Photographic Center lends itself to the requirements of running in either direction, while maintaining perfect synchronism at all times, including starting and stopping. A separate bank of motor outlets is provided at the motor patch panel (Fig. 5), and connected to the regular distributor bus through a relay. This relay reverses one pair of rotor and stator leads by remote control from a push button at the distributor start position, which also has incorporated with it the controls for switching from Record to Playback. A foolproofing relay is included which makes the reversing button inoperative until the system has come to a complete stop. Thus, the main distributor motor and its synchronous drive motor always run in the same direction, but only the projector and recorder motors are reversed, which simplifies the wiring problem. (A recent modification now also permits the projection-type footage counter to be reversed, without interfering with the remote control reset feature.)

Figure 6 shows a close-up of the control panel, which is built into the mixing console. The procedure in stopping is to open only the third phase of the main phases to the distributor system, so that all motors can be stopped "in phase." Then the reversing button is pushed, the third phase is closed again, and the system started up once more, with the projector, recorder and footage counter now running in reverse. When the proper picture or footage cue is seen on the screen, the system is again stopped in phase, the reversing button is pushed again, restoring the original polarity, and the system is ready to start rolling in the forward direction. The entire operation takes less than a minute because usually it is necessary to back up only 20 or 30 ft to correct an error.

Figure 7 shows the control panel in relation to the mixing controls. The motion picture screen is visible through the window of the monitor booth.

Modifying Recording Circuits

The biggest problem was to modify the magnetic head switching circuits and the bias and erase oscillator, so that the

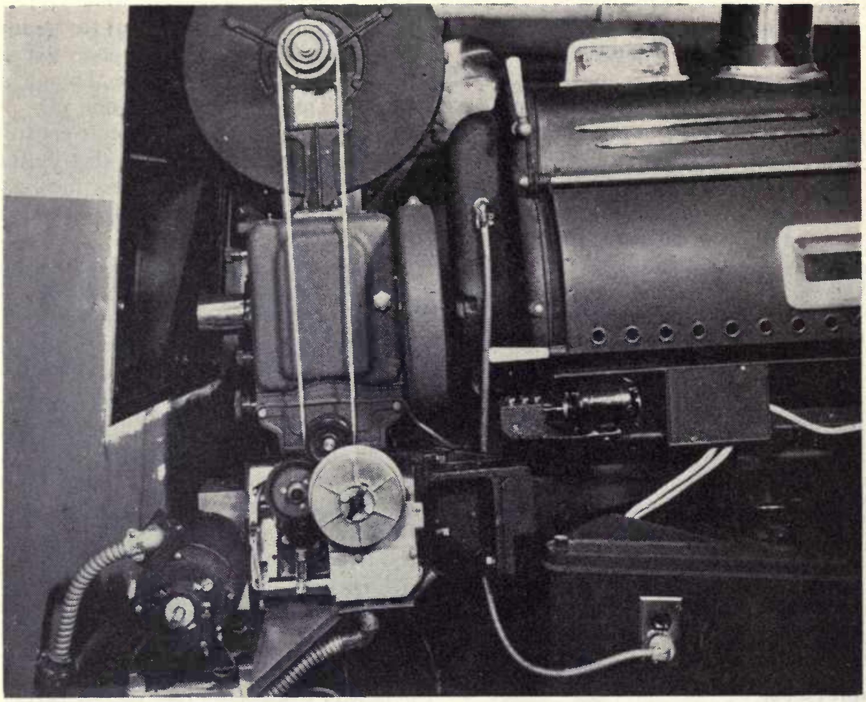


Fig. 2. Projector equipped with belt to provide take-up in reverse direction.

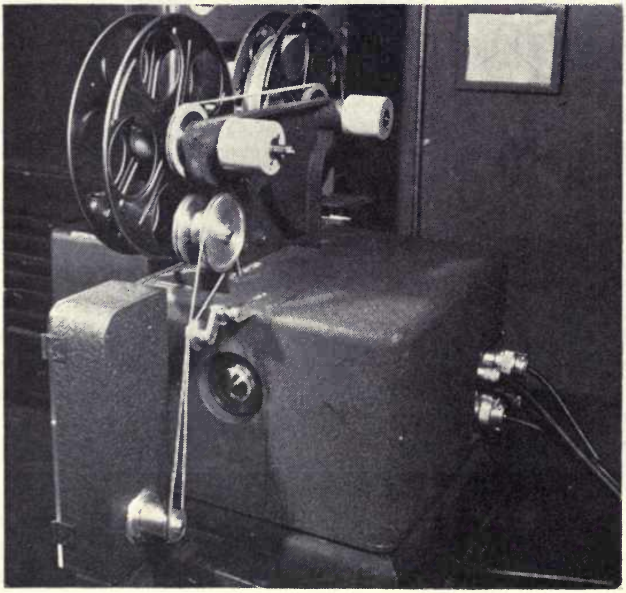


Fig. 3. Rear view of Westrex 1231 Type Magnetic Recorder equipped with special reversible take-up; also additional belt drive for Signal Corps Photographic Center loop magazine.

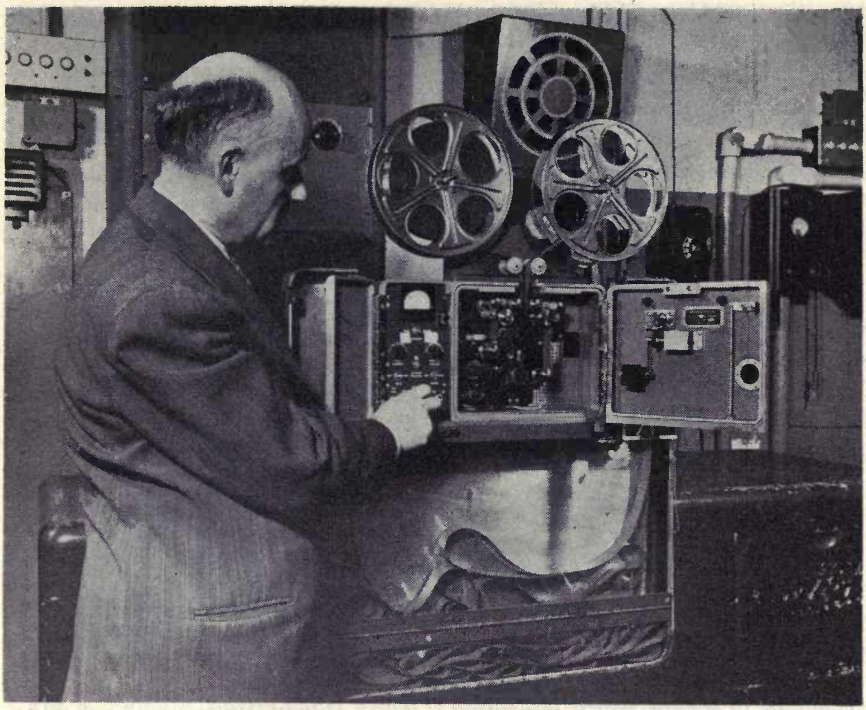


Fig. 4. Front view of Westrex 1231 Type Magnetic Recorder loaded with reels for reversible operation. The glass-door loop magazine is built into the base of the recorder.

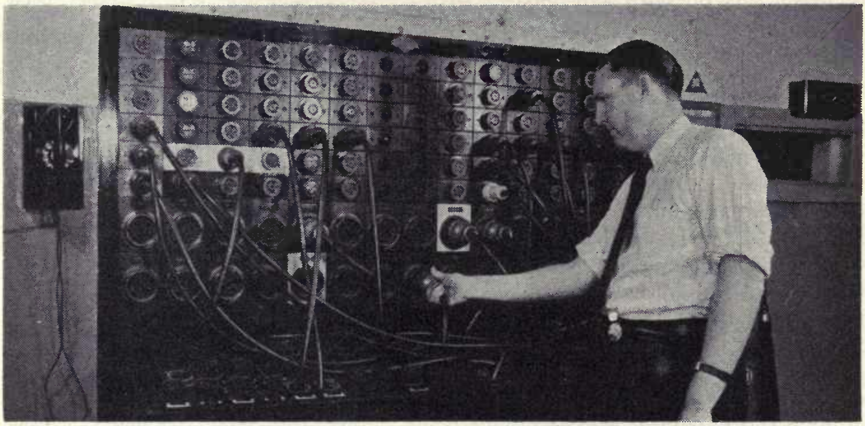


Fig. 5 The motor patch panel. The receptacles which are wired through the reversing relays are indicated by distinctive colors, as are the start positions which have reversing facilities.

transition could be made from Playback to Record with the film running, and yet have absolutely no bloop or click appear on the track. Conversely, in switching from Record back to Playback, which would be necessary if it were desired to insert a corrected paragraph in the middle of the reel after it had been completed, it is required that the end of the newly recorded track be blended into the old one without a bloop.

There would be no point in showing the exact circuit we use since each type of equipment has its own problems, but the general conditions which have to be met are as follows:

(1) The use of a separate playback head is not desirable, because this causes an unavoidable time delay. A single head should be used for both Record and Playback, with appropriate switching.

(2) A single key should be provided, with three positions: Record in one direction, Playback in the opposite direction, and a neutral position in the center.

(3) The bias and erase oscillator should be of a type which provides a separate oscillator tube followed by a driver stage and output stage. This permits the output to be controlled by the voltage on the driver stage, while the oscillator tube operates continuously, so that no trouble is encountered due to frequency shifts.

(4) When throwing the key from Playback to Record, the head should immediately switch from the input of the playback amplifier to the output of the recording amplifier. After a short delay, approximately ¼ sec, the plate voltage is applied to the driver stage of the oscillator, which should be arranged so that bias and erase currents build up gradually in about ¼ sec.

(5) When throwing the key from Record to Playback, the bias and erase currents should be allowed to die down gradually (in about ¼ sec) and then 1 sec later the head should be switched from the Record amplifier to the Playback amplifier. In other words, the important consideration, in effecting quiet transitions from Playback to Record, is to be sure that the head is switched before the bias currents build up; while, in going from Record to Playback, the bias currents must be allowed to die down gradually before the head is switched.

This last precaution, incidentally, insures against the possibility of leaving the head in a magnetized state.

(6) The neutral position of the key is utilized to keep the playback circuit open momentarily while switching from Record to Playback, so that no bloop is heard in the monitor speaker while the bias currents are collapsing.

Correcting Errors in Narration

When the system has been stopped because of an error, and the film is backed up, the sound just recorded is heard reproduced in reverse, and the picture is seen moving backward on the screen. This helps in spotting the cue at which to stop backing up. After stopping, the system is run forward again, and the playback is heard. As soon as the proper cue is reached, the switch is thrown back to Record. The narrator is then given the cue, and by the time he starts to talk, the bias current is up to its normal value.

After the reel has been completed, it is played back with the picture for checking. At this time it is often found that some error has been overlooked, and it then becomes desirable to insert a corrected sentence or paragraph. This can be done smoothly and quietly, as already described. The only additional precaution to be taken is that the inserted paragraph is not longer than the one being replaced.

Explanation of Demonstration Recording

At this point in the Convention presentation a sound recording was run to demonstrate the complete silence of what might be called the "magnetic splices" made by this technique.

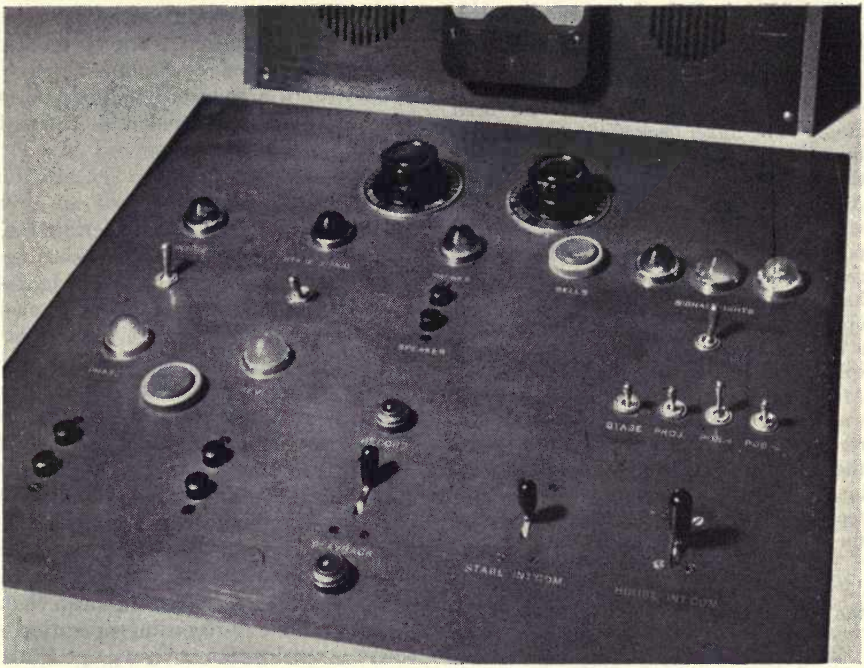


Fig. 6. Remote control panel which is built into mixing console. Complete reversing facilities, as well as switching between Record and Playback, are available.

Fig. 7. The control panel in relation to the mixing controls. The motion picture screen is visible through the window of the monitor booth.

The procedure used in recording this demonstration was to read one complete sentence and continue part way into the next sentence. The system was then stopped, as though an error had been made. The mixer backed up the film into the middle of the previous sentence, and then ran forward in Playback position. As soon as the last word of the sentence was heard, the mixer went into Record position, and the narrator proceeded to read the next sentence completely, and halfway into the following sentence. This operation was repeated for each sentence—a total of twelve sentences—so that there were actually eleven magnetic splices. After the recording was completed in this way, the sixth and seventh sentences were reread, separately, while the mixer inserted them into the record in place of the original sentences, as though they were corrections which were found necessary after the recording was completed.

The actual sound track projected was a 35-mm direct positive, re-recorded from the original magnetic film.

This system has proved successful beyond all expectations. For one thing, we find the narrator does a much better job because he can be more relaxed, knowing that if he makes an error no particular harm is done. He also does not have to keep going if he feels himself getting tired or tense, or wants to clear his throat. He simply stops and rests a moment, while we back up a little way and get ready to proceed again.

The system has proved especially valuable on rush projects, of which we have had a great many since the start of the Korean crisis. For example, Staff Film Reports, which are weekly summaries of latest battle reports made for high echelon review in the Pentagon, are narrated in the morning by this method. Immediately upon completion of each reel of narration it goes into the re-recording room, where it is mixed with the necessary music and sound effects, and transferred to the release negative, all within the space of a few hours. By the old method, we would either have to wait for the narration track to be developed and edited, or else mix the live voice with the re-recording operation, which is a difficult and generally unsatisfactory procedure.

Re-recording Operations

The technique above described is equally adaptable to all re-recording procedures as well as re-recording to sound tracks for certain types of television productions, such as newsreels. In fact, it should be adaptable to any type of production which requires the rapid assembling of narration with other sound tracks.

In the case of re-recording operations, it is entirely feasible to back up an entire bank of reproducing machines along with the magnetic recorder and projector, and we have plans for doing this in the near future. This will mean that in complicated re-recording operations, where several errors are very apt to be made in a reel, it will be possible either to correct these errors as we go along or to insert the corrections after the reel is completed, whichever happens to be more suitable. This is obviously superior to the usual procedure of doing over a complete reel because of one or two errors.

Of course, we already do all our re-recording operations on magnetic film first, and then transfer the OK take to photographic film, so that no film is ever wasted because of errors. This has been standard practice now for over two years. In this process, as with the reversing process, we have also found that there is a greater smoothness of operation and a reduction in tension on the part of the mixers, because they know that an error does not mean a waste of film. In fact, it is customary to make a magnetic recording on what would ordinarily have been a rehearsal by the old method, and it is often found that the rehearsal is a perfectly good take.

Magnetic Loops for Lip-Synchronous Operations

Another application of magnetic recording, which is still under development but will soon be in operation, is in the type of production known as foreign adaptation, or lip synchronization (lip sync for short). This is the operation in which a completed English version of a production is provided with a new sound track in which a foreign language has been substituted for the original version. Where actual dialogue is involved, the translation to the foreign version is made with a view toward having the foreign words match as closely as possible the actual syllables of the English words. The recording of this translation then becomes a very exacting process, wherein the speaker must synchronize his words as closely as possible to the actual lip movements of the person on the screen; hence, the term lip sync.

This procedure is also often used to replace original recordings by a new sound track in English, when the original is not usable due to bad pickup conditions, or to some trouble having developed in processing. Certain location jobs are often deliberately shot without sound, or with a cue track only, because of impractical pickup conditions and the sound is added later by the lip-sync process. All of the following remarks would apply equally to English and foreign lip-sync operations.

Procedure in Photographic Recording

The usual procedure throughout the industry is to break the picture down into a large number of short loops and project each of these repeatedly while an actor speaks the foreign words and attempts to match his lip movements to those on the screen. Several rehearsals are made, followed by a number of takes on film. The percentage of NG takes is usually rather high, resulting in unavoidable wastage of film. In an effort to reduce the wastage, it is customary to print several takes and combine the best portions of them. This entails considerable work in the cutting room, and infinite care on the part of the editors to accomplish a smooth job, free from noise due to handling and splicing of the film. Since considerable NG footage must be developed and printed, the process is rather costly, but this was unavoidable before the advent of magnetic recording. In any event, the process is still much more economical then reshooting the entire picture for foreign release, or making retakes where original English is involved.

Procedure for Magnetic Loops

Tremendous reduction in cost is anticipated by the use of recording on magnetic loops. Instead of breaking the picture down into loops of assorted sizes, all the loops will be cut to a few standard lengths, down to an exact number of sprocket holes. This can easily be done by adding blank leader when necessary. A number of magnetic loops are then made up to these exact sizes. The recording machine is equipped with a loop magazine, which permits convenient handling of the loops (Fig. 8). With this method it is easy to make as many takes as necessary in order to get as nearly perfect a take as possible, without wasting a single foot of photographic film. As soon as a good take is obtained, it can be played back immediately in synchronization with the picture, and as many times as desired, without even the need of stopping the film. If it is adjudged a good take, it can be immediately transferred to a photographic recorder which is always standing by ready to roll, right alongside the magnetic recorder.

In this way, the editor receives only OK takes from the laboratory, and needs only to splice them together in proper sequence to make a complete sound track. Bloop marks can be recorded from the projector in the usual way to aid in proper synchronizing.

The photographic film and its processing are thus reduced to an absolute minimum. It is conservatively estimated that film and processing costs can be reduced at least 75% by this method, while the reduction in working time in the cutting room is even greater than this.

The use of photographic film can even be eliminated completely, at this point, by re-recording the OK loops to another magnetic recorder, and assembling the completed reel by cutting the magnetic film. Moviola equipment is already available for doing this, but it has not been used as yet because of the relatively high cost of the 35-mm tape. Besides, we have plans for accomplishing this on ¼-in. synchronous tape, which would be more economical of both material and storage space. This will be touched upon in the next paper, on ¼-in. synchronous recording.

Explanation of Demonstration Film

At this point in the convention presentation a reel was run to demonstrate the result of a lip-sync operation using a magnetic loop.

A sequence from the standard SMPTE theater test reel was selected because of its familiarity to the audience. The sequence was 100 ft long, and, with the leader, made a loop 111 ft in length. While such a long loop would rarely be necessary in practice, it was used here to demonstrate that it can be done. Moreover, the great length of the loop made it possible to demonstrate that after looking at the Playback, and deciding which parts were good and which were not, it was feasible to retake the bad portions, while preserv-

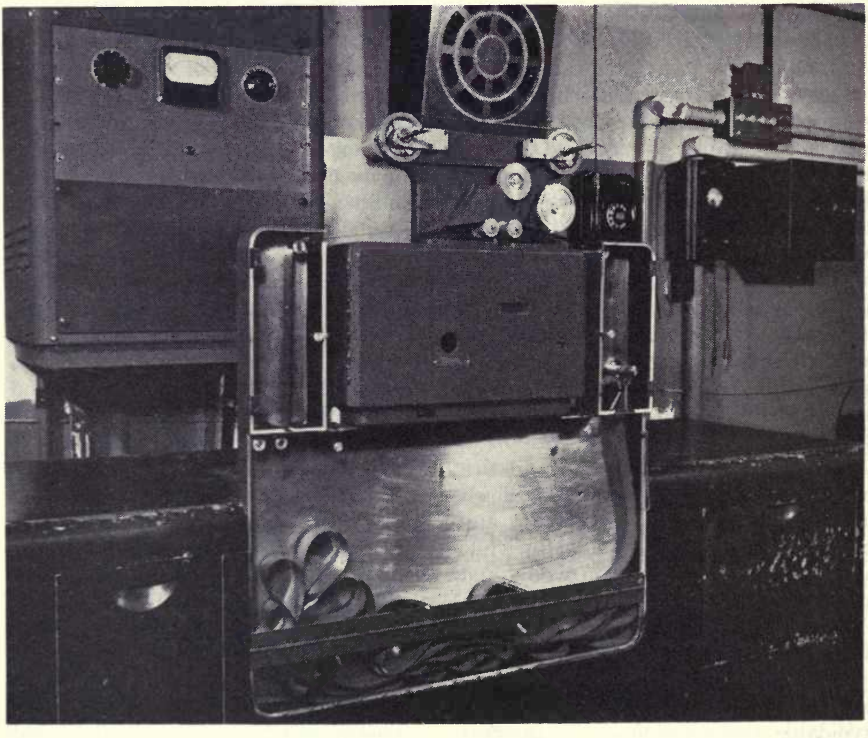


Fig. 8. Magnetic recorder threaded for loop operation.

ing the good portions. Thus, the technique for making corrections in narration is combined with the technique of using magnetic loops. The result is the production of long sequences of lip-sync without the need of editing, other than the simple transfer of the completed loop to a photographic negative for making the composite print.

Simplified Procedures

Another innovation which is being planned to simplify the lip-sync operation is to eliminate completely the use of a monitor room. We have installed facilities for doing the mixing and remote control directly on the narration stage. This means, of course, that no monitor is heard during the actual take, but the selected take is immediately heard on the playback speaker. In this way, the actor, director, mixer and script clerk become a closely knit crew without the need for an intercom system and a separate monitor room, thus simplifying and speeding up operations. Even the recording machines can be placed in a glass-enclosed booth which we have on the stage, within sight of the rest of the crew, resulting in even better coordination of the operation. Only the projection machines would remain isolated because of their high noise level.

In closing, it is desired to acknowledge the efforts of: James J. Kennedy, Jr., Chief, Transmission Section; Norman Kessel, Chief, Projection Section; Steven Szeglin and M/Sgt Sanford Hanscom, of Transmission Section; all of whom made valuable contributions to the successful completion of the work described in this paper.

Discussion

William Jordan: When you back up how do you eliminate the NG material?

Mr. Lewin: Before you start backing up, you throw over to Playback. That, of course, is essential otherwise you would be erasing and you might erase the wrong thing. So you hear the material in reverse and you also see the picture on the screen with everything moving backwards. That helps you to know just where to stop. Then you stop and run forward, still in Playback, so you're hearing the last part of the OK sentence. As soon as you reach the end of that sentence, the narrator gets his cue to start talking and you go into Record, erase whatever is NG on the film and substitute the correct dialogue.

Dr. E. W. Kellogg: One wonders whether this same system can be applied to correcting errors in tapes while photographing.

Mr. Lewin: Well, I suppose you could, but after all there is nothing you can do about the picture when they make a flub. Some day when we have electronic means for recording the picture, you will undoubtedly be able to erase the picture as well and correct them both.

Joel Tall: How fast can you make the change from Play to Record without getting the sharp erase wavefront?

Mr. Lewin: The actual speed that we use is approximately a quarter of a second although we haven't made any tests yet to determine whether we can shorten that. I rather suspect we can make it quite short, but what we used in this particular setup came out about a quarter of a second. As you noticed in the demonstration, there isn't any appreciable lag between the end of one sentence and the beginning of the next, even though we had to go through the procedure of throwing the key before each sentence.

(*All photographs for this paper are U.S. Army photographs.*)

Synchronous $^1/_4$-In. Magnetic Tape for Motion Picture Production

By George Lewin

Synchronous ¼-in. magnetic tape can be used in various stages of motion picture production. With proper modifications of existing commercial equipment, ¼-in. tape can be made to do practically everything possible with 35-mm sprocketed magnetic film. Savings in cost and storage space can be more than 90%. This new technique is equally valuable for producing motion pictures for television.

THE MANY ADVANTAGES of recording on 35-mm magnetic film are, by now, well recognized and practically undisputed. There is, however, one disadvantage in 35-mm film, and this applies to photographic as well as magnetic, namely, the fact that the sound track, at the most, need be only about ¼ in. wide; the rest of the film is wasted. In the case of photographic film, there is not much that can be done about this fact. The only solution that has been offered is to use both edges of the film, but this, at best, cuts the cost only by half, and it also introduces new problems. If the film is slit down the middle before using, it requires modifications in the recording equipment, and also in the developing and printing equipment. If it is not slit before using, there is the ever-present danger that the recording on the first side may be ruined by some accident while the second side is being recorded or printed. Also, an accident during processing would do just double the damage. In the case of magnetic recording, there are similar objections to double or multiple tracks, including the impossibility of editing the film.

Presented as the second of two papers on May 4, 1951, at the Society's Convention at the Hotel Statler, New York, by George Lewin, Chief Recording Engineer, Sound Branch, Signal Corps Photographic Center, New York.

Relative Costs and Space Requirements

If we had a satisfactory means of obtaining synchronous operation with ¼-in. tape, we could take advantage of the lower cost and smaller space requirements inherent in this medium. In fact, the savings in cost and space amount to over 90% for ¼-in. tape in comparison with single-track recordings on 35-mm film. In other words, in applications where we might want to edit the tape and, therefore, could use only single-track recordings, and could use the tape only once, the cost of ¼-in. tape, at a recording speed of 15 in. per sec, would be only about 20 cents per minute, as compared to $4.00 per minute for 35-mm tape, a ratio of 1 to

20 in cost. In terms of storage space, we could store at least two hours of recording time on ¼-in. tape in the same space required for 10 minutes of recording time on 35-mm film, a ratio of 12 to 1.

It is, therefore, obvious that any possibility of adapting ¼-in. tape to our recording needs should be thoroughly explored.

Possible Uses of Synchronous Tape

Some of the possible uses of ¼-in. tape are:

(1) The straight synchronous recording of all stage and location recordings.

The simplest and most immediate way to do this would be to record all takes on ¼-in. tape, using slapsticks for synchronizing. Only the selected takes would then be transferred to regular photographic film for editing. All of the takes would be held on the tape for protection, until the picture is completed. Relatively little space would be required for this and the cost would be negligible, as the tape could be reused.

(2) The synchronous recording of all composite music and effects tracks for foreign versions.

This material is now held on 16-in. discs. quarter-inch tape would be more economical for this purpose, because it could be reused, and the fidelity would be higher, especially for very low-level effects.

(3) All important re-recordings made to photographic release negatives for answer prints could also be duplicated and preserved on ¼-in. tape. The cost of doing this would be low because the tape could be reused after answer-print approval, and the storage space would be low. It would be desirable to do this, because if additional release negatives were required, they could be made by re-recording from the ¼-in. tape with better fidelity than by duping from a photographic master. On the other hand, it is not practical to store 35-mm tape for this purpose because of the high space requirement.

(4) All valuable music and sound effects libraries can be preserved with higher fidelity and in less space by re-recording to ¼-in. tape.

The present method of preserving libraries in 35-mm negative form is wasteful of space, and the negatives deteriorate rapidly with each printing. Much better dubbing prints can be made by re-recording from the ¼-in. tape to 35-mm direct positives, or still better, to 35-mm magnetic film, or to synchronous ¼-in. tape. This latter method would relieve the laboratory of a considerable workload.

(5) All new music and sound effects can be recorded originally and preserved on ¼-in. tape.

(6) All film-strip narration tracks can be recorded originally on ¼-in. tape for re-recording to disc masters. This is already being done at the Signal Corps Photographic Center.

(7) When suitable ¼-in. synchronous editing equipment is available, many of the re-recording operations now done with 35-mm photographic tracks could be done directly with ¼-in. tape tracks.

(8) When a lip-synchronous project is being done by the magnetic-loop process, described in the previous paper, the 35-mm loops could be transferred to ¼-in. tape instead of to photographic film. This tape could then be edited and used for the final re-recording, thus eliminating completely the use of photographic film and its processing, except for the release negative.

In view of this large number of possible applications for ¼-in. synchronous tape, it was deemed advisable to devote considerable time to the study of equipment available for this purpose, and the possible modifications which could be made to adapt it for our particular needs.

Methods for Synchronizing

Several methods have been devised for obtaining synchronous operation with ¼-in. tape. Such systems have been described in past issues of the JOURNAL,[1,2,3] but none of them offers the complete flexibility possible with 35-mm sprocketed film used in conjunction with interlock distributor, as described in the previous paper. However, a system which used automatic framing control came closest to the type of flexibility desired and was selected for further study and possible modification to meet our particular requirements.

The automatic framing control makes it possible to play back a tape recording in synchronization with a picture, once a start mark has been established on the tape. This is very useful for certain applications, such as the broadcasting of television recordings, but it was not immediately adaptable to use with our interlock type of distributor system. However, with the cooperation of the manufacturer's engineers, several modifications have been made which have greatly improved its usefulness for motion picture, as well as television, production.

Special Requirements for Synchronous ¼-In. Magnetic Tape

Our requirements, which were not met originally by any existing ¼-in. tape equipment, are as follows:

(1) The recorder must be capable of automatic remote starting and stopping, together with the distributor system.

(2) It should be possible to place a start mark on the tape prior to recording, and then use this same start mark for the playback. In other words, it should not be necessary to hunt for a start mark after the recording has been made. This is an important requirement if the recorder is to be used on rerecording operations, where alternate recordings and playbacks are necessary in rapid succession.

(3) It should be possible to make straight synchronous recordings (without automatic framing control) and re-record them to a synchronous photographic recorder, without the need of alternately clamping and unclamping any mechanical devices inside the machine.

(4) It should be possible to switch from Playback to Record, and back to Playback by remote control, without stopping the tape. This feature is necessary to permit the correction of errors in narration, as we do with 35-mm tape.

(5) It should ultimately be possible to operate the recorder with the framing control in either forward or reverse directions, and maintain synchronism with the distributor system at all times. This is recognized to be a very severe requirement, but would have to be achieved before it could be claimed that ¼-in. tape can do anything that 35-mm tape can do.

The Advantages of Interlock Over Synchronous Systems

An explanation should be made at this point of the reason we favor the use of an interlock distributor system over a straight synchronous motor system, which is used in some other studios. We list the following reasons:

(1) We have never been fully convinced that a straight synchronous system is capable of exact synchronism, if we define this term as plus or minus zero frames. In order to get a synchronous motor up to speed, in exactly the same length of time each time that it is started, it must be a generously oversized motor and it must be unaffected by changes in load conditions due to temperature, line voltage changes, and various conditions of binding in the machine, especially in the case of projectors.

(2) The sudden starting of a machine repeatedly is certainly bad practice from a maintenance standpoint, es-

pecially if you are dealing with a large number of delicate and expensive machines, such as re-recorders and projectors.

(3) With a straight synchronous system, it is certainly impossible to stop, and run backward and forward, without losing synchronism.

The interlock distributor system eliminates all of these objections.

The Fairchild Synchronous System

No attempt will be made to describe fully the theory of operation of the system we selected for further study, as this has been done adequately in a paper already published in the JOURNAL.[2] Suffice it to say that 60-cycle intelligence is recorded on the tape, as a control track, along with the program material. This control track is actually a 15,000-cycle carrier modulated by 60 cycles from the line, so that it can be recorded and reproduced by the same heads as the program, but separated by appropriate filter circuits. The tape itself is transported during recording at exactly 15 in. per sec by a capstan, which is locked to the synchronous motor drive, and which permits no slippage of the tape. During playback, this synchronous lock is disconnected mechanically, and the capstan is puck-driven at a ratio which, in the absence of any other control, would drive it at about 2% above synchronous speed. However, the 60 cycles from the control track is picked up by the playback head, separated from the program by appropriate circuits, amplified, and fed back to one phase of a two-phase control motor, which is also coupled through pucks to the capstan. The other phase is powered by line frequency. This control motor is poled so as to slow down the capstan to approximately synchronous speed. The actual control circuit functions on a phase basis so that stability is achieved when the 60 cycles from the control track matches the 60 cycles from the line, both in frequency and phase. By this method, the tape is always reproduced at a speed which corresponds to exact synchronism with the line frequency, regardless of stretch or shrinkage which may have developed in the tape during the time elapsed between recording and playback. Any slight slippage between tape and capstan during playback is also compensated for by this method.

The Automatic Framing Control

The automatic framing control is an accessory device, which was originally intended to permit playback of the tape in synchronism with a projector. It provides a means for slowing up the starting time of the tape while the projector catches up with it, and then automatically switching over to synchronous operation after normal speed is obtained. It makes use of two small selsyn motors, one of which is coupled to the projector and the other, through a differential gear, to the tape capstan.

Modifications in Fairchild System

With this very sketchy description of the theory of operation in mind, we will now consider the adaptations which have been made to meet the requirements enumerated above.

(1) To provide automatic remote start and stop with our distributor system, a separate interlock motor is provided which is geared to a small selsyn motor. This is shown at the right of the recorder in Fig. 1. This selsyn motor performs the same function as the one which is coupled to the projector in the original application of the Fairchild equipment. A relay is also provided which turns on the a-c power to the tape recorder the moment the distributor starts running. (Both the selsyn motor and relay are in the small black box attached to the left end of the interlock motor.) The framing control then takes over until normal

Fig. 1. Synchronous ¼-in. tape recorder and accessory equipment.

The framing control unit is directly above the recorder. The interlock motor (which is ordinarily out of sight in an accessory cabinet) is seen at the right with the small black box attached containing the selsyn motor and tape-starting relay. The remote control boxes, seen in front of the interlock motor, can be extended on cables as far as desired. The motion picture screen is visible in the background. (*U.S. Army photograph.*)

speed is reached, when it switches over to synchronous operation.

(2) In order to make it possible to place a start mark on the tape before recording, and to use that same start mark when making the playback, it is necessary to use the automatic framing control when recording, as well as when playing back, instead of on the playback only, as originally intended. This posed an interesting problem, since the framing control depends upon the presence of a control track to tell it when to revert to synchronous speed. It was believed at first that the track being recorded at the moment would serve this purpose, but this proved to be a fallacy.

The control circuit ordinarily depends upon detecting the difference in frequency between the control track being reproduced, and the line frequency existing at the time of playback, and then reducing this difference to zero. If the playback head picks up the control track which is being recorded at that moment, there is no difference in frequency even though the tape speed is not normal, and the result is that the capstan stabilizes at a speed about 2% slower than synchronous speed. If an attempt is made to play back a recording made in this way, it is found

that the control system does not have enough control to hold the tape down to this speed, and it occasionally slips out of synchronization.

The most practical way to overcome this problem would be to install a mechanical means of locking the synchronous motor to the capstan at the moment the framing unit relinquishes its control. However, since this would have taken considerable time to design, a simpler solution was sought in the meantime. This resolved itself into installing a relay in the framing unit which disconnects the control power at the moment the framing unit gives up control. It was found that the mechanical drag of the control motor, coasting along, was just about sufficient to hold the capstan at approximately synchronous speed during recording. During playback, of course, the regular control power is automatically restored by the same relay, so that the tape is reproduced at exactly the same speed at which it was recorded. Thus, exact synchronism is maintained.

(3) In order to avoid the need of locking and unlocking the mechanical coupling between the synchronous drive motor and the tape drive capstan when changing from Record to Playback, a relay has been installed which performs the same function as the one just described in connection with the automatic framing control. This relay is installed within the recorder itself so that it functions even though the framing-control unit is not used. The control motor is left coupled to the tape capstan at all times, so that no change has to be made between Record and Playback other than to operate the usual control switches.

(4) In order to provide means for switching back and forth between Playback and Record without stopping the tape, it was only necessary to by-pass the fool-proofing circuit, which is purposely included in the standard machine to minimize the possibility of erasing recorded material accidentally. The control for this facility is provided in a small box at the end of a long cable, so that the mixer can control this remotely, besides starting and stopping the machine. The reversing is still done by the operator at the recorder, but it is planned to make this a remote control also.

At the present time this facility is used for nonsynchronous recording only, as it has not yet been definitely established that the replacement of one control track with another can be done without occasionally losing synchronism. A probability factor is involved here, depending upon whether the new control track is in phase with the old one, or possibly gains or loses more than half a cycle. If necessary, a method can probably be devised to insure that the new control track remains in phase with the old one.

(5) In order to achieve facilities for running in reverse with the framing-control unit, additional relays and some circuit changes will probably be necessary. Complications may also arise from the fact that, in reverse, the playback head, which picks up the control track, precedes the point at which control is applied to the driving capstan; whereas the control system was designed to work the other way around. The achievement of this facility would be very desirable, as it would break down the last barrier against complete equality between 35-mm and ¼-in. tape for motion picture and television production.

It might be appropriate at this point to discuss briefly the method we have used to check the accuracy of synchronism of our ¼-in. tape recording tests. The obvious method of photographing someone speaking in front of a camera is not very accurate if we are interested in detecting small errors in synchronism, such as two frames or less. Besides, many speakers have a disconcerting

type of lip movement which makes them look out of synchronism even on a live television show. The cost of photographing and printing is also a drawback. The method we have adopted is to record a voice simultaneously on 35-mm and ¼-in. tape recording equipment. The two tracks are then played back in synchronism, with the outputs mixed together. In this way deviations of even one sprocket hole are instantly detectable, and no photographic film is used. Even the voice can be eliminated and replaced by a loop having a series of clicks. By this method we have verified time and again that the system will remain in perfect synchronism continuously for complete 33-min takes.

Of course, it is not to be inferred from this that we consider an error of one sprocket hole to be serious, but it should be borne in mind that errors may accumulate in the same direction during the various steps of production, and if they add up to two frames or more they can become very disconcerting, and detract from the realism of a production.

Explanation of Demonstration Film

At this point in the Convention presentation a film was run to demonstrate the result of lip-synchronizing a number of loops by a combination of the methods discussed in this and the previous paper. This film was made in the following manner:

A number of typical picture loops were obtained and cut to exactly equal lengths by adjusting the leaders. A 35-mm magnetic loop was cut to this same length. Two projectors were used so that, as soon as one loop was completed, rehearsals could be started on the next one without delay. The actual procedure was to keep recording on the magnetic loop until a good take was obtained. This was immediately played back with the picture—which can be done by this method without the need for even a momentary stop. If the take was not considered good enough, additional ones were made immediately. If it was good, it was transferred immediately to the synchronous ¼-in. tape, and at the same time the next loop was started up for rehearsals.

The actual time consumed from the time the first loop started rolling until all of the selected takes were transferred to ¼-in. tape, was possibly a half-hour, which would determine the cost of the narrator's time. Of course, after this point, because we do not yet have professional-type editing equipment for ¼-in. tape, we spent considerable time editing the tape into one continuous length to match the picture, which also had been reassembled into one piece. But when this had been accomplished, it was necessary only to make a single transfer to 35-mm photographic film, using up only the exact amount of film as the completed project, instead of at least five times the amount of negative and print which would be necessary by the conventional method, to say nothing of the editing time required to juggle words back and forth to obtain the required perfection of synchronism.

Before closing, mention should be made of some of the disadvantages of ¼-in. tape, because it is not our intention to leave the impression that it is ever going to supplant 35-mm completely, in the foreseeable future. The most important disadvantage is probably the complexity of the synchronizing system, relying as it does on delicate electronic circuits, and the accurate reproduction of a relatively low-level control track. The control system also causes some increase in flutter content.

Another disadvantage is the frailty of ¼-in. tape. It is more easily damaged by rough handling and is easier to snarl up in rewinding than is 35-mm film.

A third disadvantage is the unfortunate tendency of ¼-in. tape to permit leakage of the magnetic image to adjacent layers of the roll. This "print-thru" effect apparently has not bothered radio broadcasters very much, but in motion picture narration, where there are numerous blank intervals between isolated sentences, there is often heard a distinct, though faint, anticipation of

the first few words of a sentence during the preceding blank interval. This is usually not noticed by the average audience and should not be classed as a serious disadvantage. It is likely, however, that further research will eliminate this effect.

In spite of these few drawbacks, it is to be hoped that the many other great advantages will encourage the increasing use and development of this medium for motion picture and television production.

In conclusion, appreciation is expressed to Wentworth Fling and Larry Saper of the Fairchild Recording Equipment Co., and also to Abraham Seidman of our Sound Branch, for their cooperation in making the modifications described in this paper.

References

1. R. H. Ranger, "Sprocketless synchronous magnetic tape," *Jour. SMPTE*, vol. 54, pp. 328–336, Mar. 1950.
2. D. G. C. Hare and W. D. Fling, "Picture synchronous magnetic tape recording," *Jour. SMPTE*, vol. 54, pp. 554–566, May 1950.
3. W. T. Selsted, "Synchronous recording on ¼-in. magnetic tape," *Jour. SMPTE*, vol. 55, pp. 279–284, Sept. 1950.

Discussion

JOHN FRAYNE: I think this is the first instance where we have had a comparison of the sprocket-hole film versus the tape. We have had the protagonists for both sides who have made claims, and I think this is a very interesting contribution to the literature. I'd like to ask one question: Do you foresee in the near future an extension of this synchronized tape to general motion picture production such as we have in the larger studios?

MR. LEWIN: Yes, I really do. In fact, I, for one, am trying very hard to push the application of this system because I feel that we can save so much film and so much time in the usual intermediate processes that go on before the picture is ever released; and I am convinced that we can certainly maintain synchronism. That is the least of our problems. I think the biggest problem now is professional-type editing equipment, so you can do a smooth job when you edit this tape and that is something which will have to be learned by the personnel. The people that are accustomed to working with 35-mm film are generally antagonistic to playing around with this dinky little tape, but I think that's just a matter of getting accustomed to it.

COL. RICHARD H. RANGER: I didn't want to ask a question. I just wanted to thank Mr. Lewin for giving us an objective in this work, and for setting up the various merits of the two systems. We should see what we can do to meet the challenge that he has given us on quarter-inch tape.

New Video Recording Camera

By F. N. Gillette and R. A. White

The camera described has been designed specifically for video recording purposes, and therefore differs in many respects from the usual conception of a 16-mm camera. To accomplish intermittent film pulldown within the short space of time available, a multiple skip claw movement is utilized. The usual mechanical shutter is eliminated, but a device is incorporated to actuate an electronic shutter, which at the same time provides for the transition from 30-frames/sec television to 24-frames/sec film speed. In order to obtain the necessary film stability at the aperture, and to eliminate any tendency to scuff or wear off film emulsion at this point, a vacuum-operated film gate is utilized, which permits the camera to be operated for rather long uninterrupted periods of time. Provision is made within the camera for the simultaneous recording of sound, at standard spacing for correct sound synchronization.

Video recording, being a relatively new art, presents many new problems. For obvious reasons of economy, 16-mm film is used almost exclusively. However, the equipment used in the process must have the professional quality and ruggedness previously available only in the 35-mm field. Although the camera operates at standard frame rate, the pulldown time must be extremely short, and a transition from 30-frames/sec television to the 24-frames/sec film rate is required. It is also necessary that the camera be capable of operating without interruption or attention during recording of a half-hour or even full-hour program. In addition, provision must be made for recording program sound simultaneously with the picture, in correct synchronization.

A contribution by F. N. Gillette and R. A. White, General Precision Laboratory Incorporated, Pleasantville, N.Y.

This new camera has been designed specifically for video recording, with adequate provision for the foregoing requirements.

Method of Operation

Before describing in detail the camera's design and construction, it is necessary to describe briefly the basic method of recording for which this camera was intended. Figure 1 is a diagram showing one possible time relationship between television fields, recorded film frames and film pulldown. The diagram shows that one half of a television field is discarded during pulldown for every two full fields (or one full television frame) which are recorded. Since the picture to be photographed appears as successive lines on the face of a cathode-ray tube, some means of preventing film exposure during pulldown must be incorporated. This might be an accurately timed me-

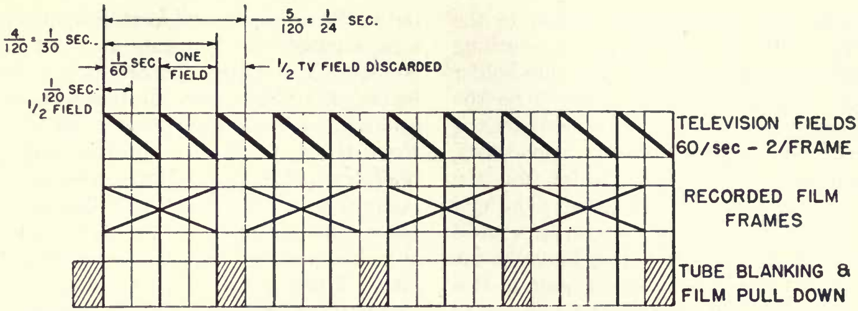


Fig. 1. Timing diagram, illustrating transposition from 30-frames/sec television to 24-frames/sec film recording.

chanical shutter, or it might be a so-called electronic shutter, by means of which the cathode-ray tube is blanked out during pulldown. The latter method is the one used with this new camera, as is the time cycle illustrated. Referring to Fig. 1 again, it will be seen that since the television fields are continuous, the specific moment at which a film frame starts is immaterial, the main requirements being:

(1) that the electronic shutter remain open for the length of time required for a full television frame and no more, and

(2) that pulldown action and shutter action are correctly timed with respect to each other, as in the case of the normal mechanical shutter.

Further study of the time diagram indicates that the time available for pulldown is that of one half of a television field, or 1/120 sec. However, this full time is not available in actual practice for several reasons, the major one being persistence of the cathode-ray tube phosphor. Because the picture is put on the face of the cathode-ray tube in the form of lines, one after another, the film in the camera is exposed to the maximum decay time of the first line only, and to each succeeding line of that frame for a uniformly decreasing length of time. Unless the film is permitted to remain in the aperture for a reasonable period after the last scanning line appears and the electronic shutter closes, a very definite density difference, or splice line, is apparent, marking the join-up of the first and last portions of the frame. This problem of picture splice is treated in detail in a paper by F. N. Gillette.[1]

In addition, a more comprehensive treatment of the electronic shutter and the associated equipment is available in another article by F. N. Gillette, G. W. King and R. A. White.[2]

General Description

Figure 2 is a picture of the complete camera with all doors closed and lens and film magazine in position. The door used in normal operation is the one toward the front of the camera, with its latch indicated at point 1, while the door to the rear half can be opened whenever necessary for access to the modulator.

The magazine shown is a standard 16-mm magazine of 1200-ft capacity, manufactured by J. M. Wall, Inc. Its take-up pulley is spring-belt driven from a simple friction clutch located within the camera housing.

The lens mount accepts the Eastman Cine Ektar lens, and the one illustrated and normally supplied is of 40-mm focal length and has a maximum aperture of $f/1.6$.

The power "on-off" switch mounted in the camera base is indicated at point 2, to the left of which is the "power-on"

pilot light, followed still further to the left, at 3, by the film-break warning light next to which is the fuse-holder cap. In a comparable position on the opposite side of the camera base are the necessary electrical cable connectors, and a small hose connector for the vacuum supply to the gate. The end bell of the camera motor can be seen at point 4, but the threading knob on the end of the motor cannot be seen in this view. On the rear of the camera at point 5 is the exit port for use with continuous processing equipment. The window for the footage counter is also located in the back wall near the exit port, but is not visible in this view.

Figure 3 is a close-up view with operating door open, showing the film path in detail. At point 1, the film is pulled out of the magazine and forms a loop before it enters the film gate at point 2. At point 3, it forms another loop as it leaves the film gate and continues around the drag sprocket at point 4. From there, it follows around the scanning drum at 5, under a tension roller at point 6 in a tight loop and then it is taken up at point 7 by the upper sprocket and fed back into the magazine. Point 8 shows the roller on the automatic stop device which functions in case of film breakage.

All castings are of aluminum alloy, shafting is stainless steel, wherever practical, and double-shielded prelubricated ball bearings are used throughout. All gearing is steel mating with laminated phenolic, with the exception of the motor shaft gear which is nylon.

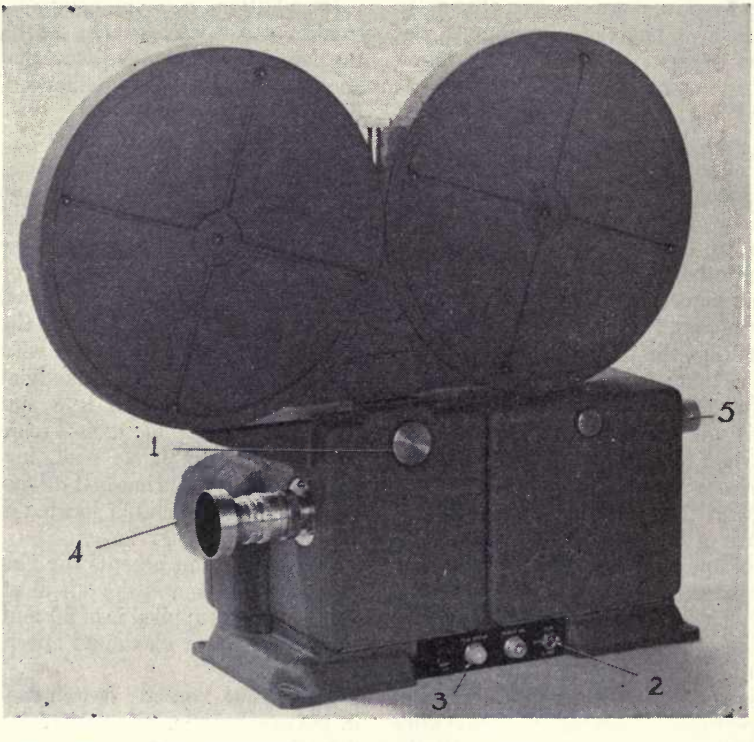


Fig. 2. Complete video recording camera.

Intermittent Design

The one-half field or 1/120 sec maximum available pulldown time, translated into degrees, results in a figure of 72°, which is not an exceptionally fast pulldown. In practice, however, because of the phosphor persistence effect previously mentioned, it is necessary to decrease this time to less than half of the theoretical maximum.

A claw-type intermittent is used, the main components of which are a vertical cam, two lateral cams mounted on a single shaft, plus the claw or shuttle. The lateral cams are rotated at 1440 rpm or once per film frame. The front lateral cam actuates the claw in a forward direction for engagement with the sprocket holes of the film just prior to pulldown. The rear lateral cam actuates the claw in the opposite direction to disengage it at the end of pulldown. Since these cams are both mounted on the same shaft and rotate once per film frame, there is one claw entry and one retraction per film frame. The vertical cam which, as the name implies, actuates the claw in an up-and-down

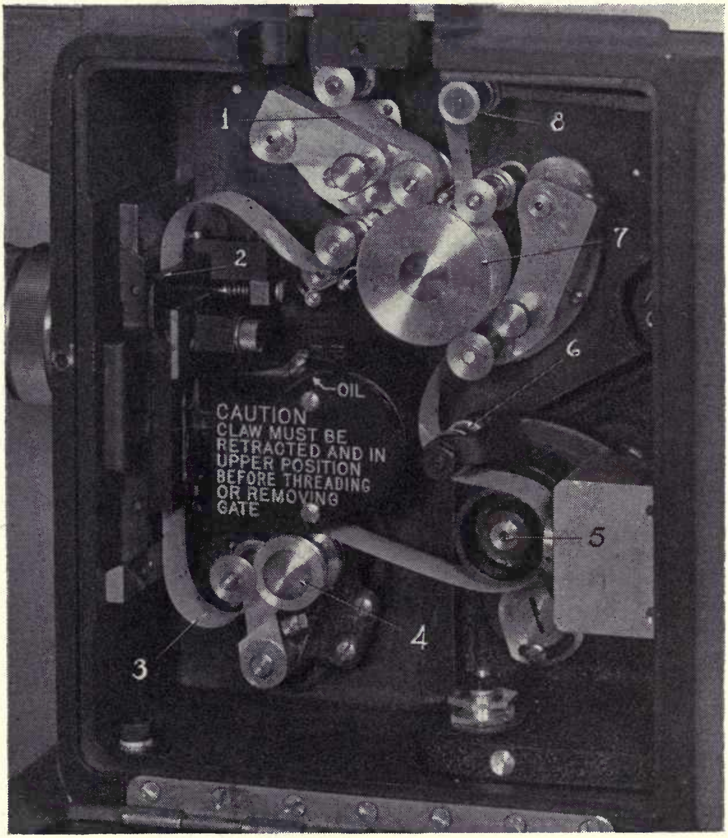


Fig. 3. Interior view of camera, showing complete film path. The vacuum-actuated film gate can be seen between the upper and lower film loops, and notes on threading appear on the cover of the intermittent housing.

action, is timed with the lateral cams through a pair of 3-to-1 ratio helical gears, and is rotated at three times frame speed. As a result of this multiple-skip design, the claw makes three excursions up and down per frame, one out of every three downward excursions being used for pulldown. A high-speed pulldown is thereby obtained, while shaft and cam speeds remain uniform.

The actual pulldown time is one-third of the vertical cam angle (⅓ of 85°), or 28.5°. Allowing some time for claw entry and retraction, the total time during which the claw is in contact with the film is in the order of 31°. The difference between the aforementioned 72° and the latter 31° is the time available for the film to remain stationary in the aperture after the last scanning line appears, and thereby approach equalization of exposure to the phosphor's decay before the next pulldown occurs.

It was previously determined by experiment that movement of the film within the aperture in excess of 0.00007 in. (which is 0.025% of aperture height) during exposure would result in a noticeable pairing of picture line structure. It was believed, therefore, that even the most accurate register pins, entering or leaving the film during exposure, would cause more film movement than could be tolerated. Therefore, since there is not sufficient time available before or after pulldown to actuate register pins fully, they are omitted.

The camera is powered by a 3600-rpm hysteresis synchronous motor, which drives the vertical cam shaft at 4320 rpm. Since it is difficult to retain oil or grease on the cams at this high speed, a wick lubrication system is incorporated. The wick continuously wipes the vertical cam surfaces, keeping them sufficiently lubricated. This, incidentally, is the only part of the camera requiring frequent replenishment of lubricant. Vibration is kept to a minimum by dynamically balancing both intermittent shaft assemblies, all cams and the motor armature. The items are individually balanced so that, in case of field replacement, balance is still maintained.

Shutter Action

The electronic shutter, as such, is not a component part of the camera, but rather a part of the associated electronic equipment. The camera opens the electronic shutter by delivering to it a correctly timed electrical pulse. Thereafter, the shutter remains open for a full television frame, its closing being controlled by its own circuitry.

The timed electrical pulse is obtained by means of a light source, a light aperture, a photocell and a rotating disc. The rotating disc, known as a "pipper" disc, since it produces pips or pulses, is mounted on the vertical cam shaft, at the opposite end of the shaft from the cam. It thereby rotates at three times frame speed (or 4320 rpm) and being 4 in. in diameter, has a high peripheral velocity. Near the periphery of the disc is a small radial slot, about 1⁄16 in. wide and 3⁄16 in. long. Adjacent to the pipper disc is a member of the camera gear train, which rotates at ⅕ frame speed and has five holes equally spaced around its periphery. Designated as the cycling gear, it overlaps the pipper disc so that the slot in the disc and one of the holes in the cycling gear rotate into line once per frame. From the light source, through a light aperture on one side of this assembly, a light pulse is impinged on a photocell located on the opposite side. The pulse occurs each time the slot in the disc and a hole in the cycling gear rotate into line with the light aperture. The high peripheral velocity of the pipper disc produces a steep wave-front pulse of short duration, while a pulse repetition rate of once per frame is obtained by the masking of the cycling gear, without which there would be three pulses per frame. The angular relation between the vertical cam and the slot in the pipper disc determines the time re-

lation between film transport and shutter opening.

As previously mentioned, no motion of the film in the aperture can be tolerated during exposure, therefore the claw must be free of the film before the shutter opens. The camera is timed, therefore, to open the shutter the moment the claw is free of the film at the end of pulldown.

Figure 4 shows the removable assembly consisting of photocell and pipper lamp, designed for ready removal and rapid replacement of either photocell or pipper lamp. Replacement of either does not disturb shutter timing, and can be done in a matter of seconds, without the necessity of shutting down the camera, should either fail during operation.

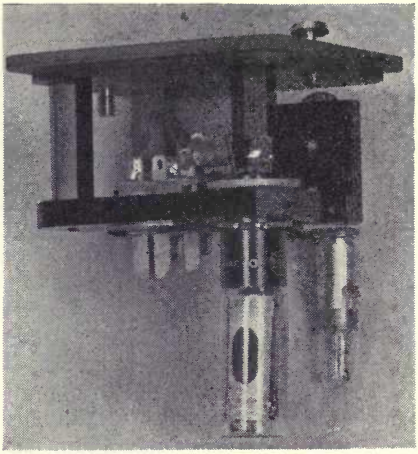


Fig. 4. "Plug-in" assembly of photocell and pipper lamp. Note coin-slotted captive screws which anchor assembly in place on camera.

Film Gate

During the early development stages of this camera, the usual spring-loaded pressure shoe was used in the film gate to hold the film in the focal plane in contact with the aperture plate, and to obtain the necessary film friction in the gate.

However, it was believed that if another means could be developed which would provide the necessary film friction during pulldown and retain the film securely at the aperture during exposure, without introducing sliding contact pressure on the emulsion surface of the film, long-time operating conditions would be more favorable. This led to the development of the vacuum-actuated film gate now in use in this camera.

The front half of this device contains the aperture plate, side guide rollers at top and bottom, and a spring-retained shoe supporting the film against the claw during pulldown. The use of a spring-retained surface to back up the film is a desirable safety feature. Should the claw lose registry during a stand-by period, the spring permits the claw to ride over the film during the first pulldown stroke until it picks up the perforations. If there was a solid backing at this point, the claw, once out of registry, would tend to make its own perforations, and would not immediately get back into correct index. It should be understood, however, that the claw does not normally lose index with the film, but because there are no register pins, it can do so if the film is accidently moved within the gate during a stand-by period.

The rear half is the hinged part of the gate, and is held closed (or open for threading) by a toggle-action device. A rigidly fastened vacuum shoe replaces the usual spring-loaded pressure shoe directly behind the aperture in this rear half. When the gate is closed, there is a total of about 0.012 in. clearance between the surface of this vacuum shoe and the aperture plate. The vacuum shoe is a rectangular steel plate, about 1 in. wide and ¾ in high. Its center portion, which is centered behind the aperture, is relieved for a depth of 0.010 to 0.015 in. over an area corresponding to the picture. This surface is finished with a flat black lacquer. The rest of the shoe surface is lapped and

polished. Above, below and along each side of the image area is a series of small holes, connected to a continuously evacuated chamber just behind the vacuum shoe. When the film is in position for exposure, it tends to seal the vacuum holes and is thus held firmly in position in all directions. The vacuum holes in the area of the sprocket perforations, however, are so spaced that as pulldown commences, the vacuum is partially relieved by the film perforations passing over these holes and opening the vacuum system to atmospheric pressure. But as pulldown nears completion, the vacuum holes are once again sealed. In this manner, film tension during the major part of pulldown is decreased, making for less wear and tear on the film, while providing ample friction just prior to the completion of pulldown. Thus the "valve" for modulating the degree of vacuum is the film itself.

By the use of this system, it is possible to obtain ample gate friction and accurate film location. In addition, because the emulsion surface of the film does not come in sliding contact with the aperture plate, but instead clears it at all times by several thousandths of an inch, no scuffing of the film emulsion is encountered. As a result, long uninterrupted runs may be made, and only occasional cleaning of the film gate is necessary. By adjusting the steady-state degree of vacuum on the system, optimum conditions can be obtained for various film characteristics during operation. Most films require in the order of 20 to 22 in. of vacuum, although some need as little as 16 in. while others require as much as 27 or 28 in.

Sound Recording and Stabilization

Variable density sound is recorded by a galvanometer-type light modulator, manufactured by J. A. Maurer, Inc. It is expected that a new model modulator, interchangeable with the present one, will soon be available, which will permit

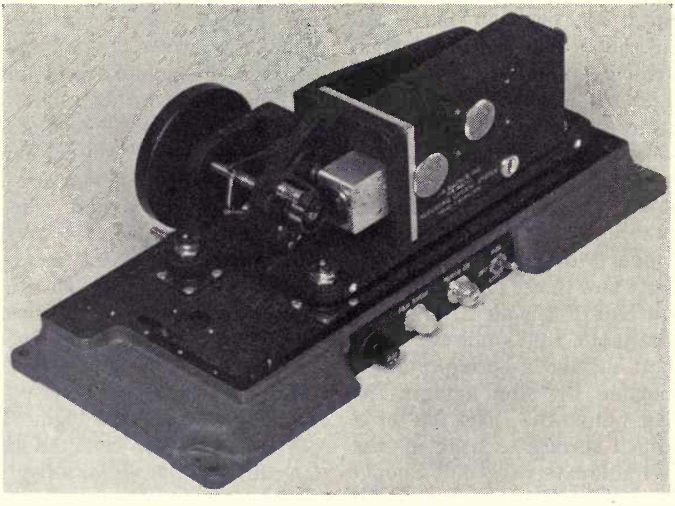


Fig. 5. Camera base with main housing removed, showing shock-mounted sound recording and stabilization equipment. The small hose connector for supplying vacuum to the film gate is visible just below the flywheel rim.

either variable area or variable density recording to be used, with only a simple adjustment required for change-over from one to the other.

Following the lower loop out of the film gate, the first component of the sound stabilization system is the film-driven viscous drag sprocket. From this, the film travels around the scanning drum which is rigidly coupled to the flywheel. A spring-loaded roller arm, following the scanning drum, combines with the drag sprocket in maintaining uniform tension on the film. This tension is approximately 5 to 6 oz. With this arrangement, no pressure roller is required on the scanning drum. In flutter tests, using this camera as a film phonograph with 3-kc standard flutter test film, flutter measures a maximum of 0.14% rms.

With the exception of the viscous drag sprocket, the entire sound recording and stabilization mechanism is assembled on a separate shock-mounted platform. Figure 5 is a picture of the camera base with the shock-mounted platform assembly in place, the main camera housing having been removed. All components are accurately and rigidly located on a casting but isolated from mechanical noise and vibration. The mechanism is jig-located on the camera base at assembly, giving correct positioning of components for alignment with the balance of the camera mechanism when the main housing is assembled with the base.

Additional Mechanical Features

The only power-driven sprocket in the camera is the combination feed and take-up sprocket which serves to feed film out of the magazine into the film gate via a compliant loop, and also to pull the film from the sound stabilizer and feed it back into the magazine (or out the rear port in case the camera is used with continuous processing equipment). Following the take-up side of the sprocket is a spring-loaded roller arm which actuates a microswitch. Should the film break, or not be properly taken up in the magazine for any reason, or should the camera run out of film, this device automatically stops the camera and turns on the film-break warning light.

With camera lens and electronic focus properly adjusted, no difficulty is encountered in resolving the line structure of a correctly interlaced picture. Furthermore, once the camera lens is correctly focused, it operates as a fixed-focus device.

Since sound and picture are recorded simultaneously at standard spacing of 26 frames, it is possible to make direct positive film, and, with the use of continuous rapid processing equipment, project the picture on a screen within 60 sec of its transmission, for the intermediate film method of theater projection television.

Although most of the work with this camera at General Precision Laboratory has been concerned with the handling of direct positives, the camera is equally capable of producing negatives, from which the necessary prints for distribution to network stations can be obtained.

References

1. F. N. Gillette, "The picture splice as a problem of video recording," *Jour. SMPTE*, vol. 53, pp. 242–255, Sept. 1949.
2. F. N. Gillette, G. W. King and R. A. White, "Video program recording," *Electronics*, vol. 23, No. 10, pp. 90–95, Oct. 1950.

Practical Solution to the Screen Light Distribution Problem

By Charles R. Underhill, Jr.

A screen is described having a gradational perforation pattern in each of the side areas between the central portion and the extreme sides of the screen. The central portion of the screen is uniformly perforated and the extreme side areas are of unperforated screen material. This perforation design tends to compensate for the uneven light intensity from modern carbon-arc lamps, resulting in a practically even light reflection from the surface of the screen. This paper describes a screen which has been designed to have a higher reflectance in the side portions of its surface than in the center, and reasons are presented why this screen is a practical solution to the uneven light distribution problem.

It is a well-known fact that the side-to-center distribution of light on the common uniformly perforated, or unperforated, sound motion picture screen, when illuminated by the modern carbon-arc lamp, is limited to about 80%[1] under the most favorable conditions of projection equipment adjustments. In actual practice the brightness in the side portions as compared with the brightness in the center of the screen is often much less.

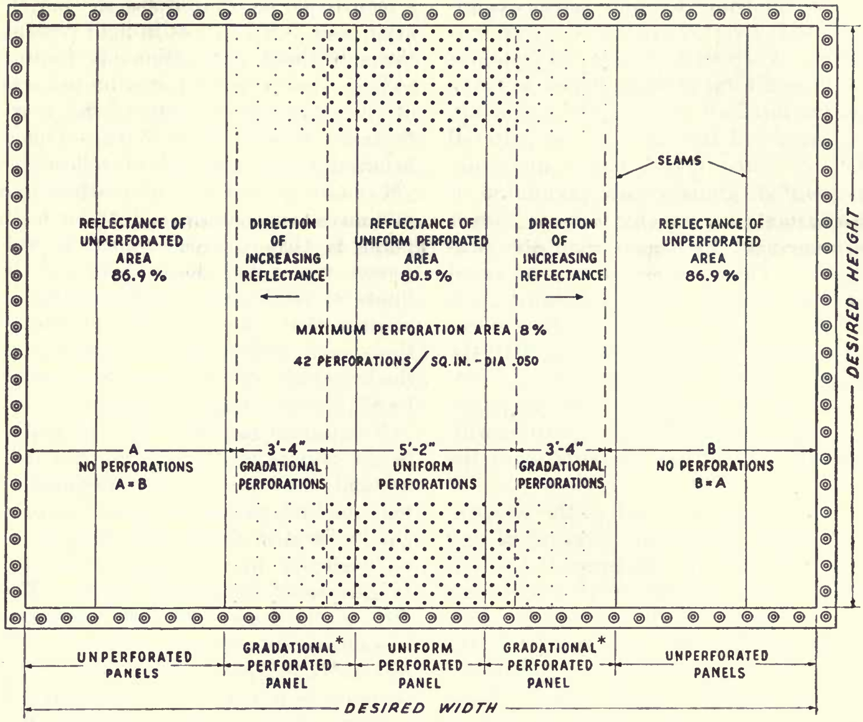
In a specific instance,[2] measurements on a screen 25 ft wide showed a brightness of 9.6 ft-L at the center of the screen, 9.2 ft-L at a point 4 ft from the center, 8.1 ft-L at a point 8 ft from the center, and 6.2 ft-L at a point 12 ft from the center. The brightness in the side portions as compared with the brightness in the center was 64.5%. This is believed to represent about the average of the ratios which exist in motion picture theaters today.

The various causes of uneven distribution of light on the screen and other light source problems are generally known and have been published in the Journal and elsewhere.[3-9] They become manifest as observable results seen on a screen surface, beyond which the screen is not otherwise involved.

The screen which appreciably compensates for the uneven illumination from the light projected upon it is known as the Snowhite Evenlite* perforated sound motion picture screen. Its design is based on a patented perforating technique which compensates for and, at least partially, counteracts the difference between the illumination

Presented on May 2, 1951, at the Society's Convention in New York, N.Y., by Charles R. Underhill, Jr., Engineering Products Dept., RCA Victor Division, Camden, N.J.

* Manufactured for and distributed by RCA.



The RCA Snowhite Evenlite Perforated Motion Picture Screen, Patent No. 2,133,097.

at the center of the screen and the side portions. Maximum perforation of 8% of total area at the center of the screen is employed where the illumination is brightest, and where the speakers behind the screen are commonly located. This portion of the screen's total area is equivalent to the common uniformly perforated screen, and has 42 perforations per square inch, each perforation being 0.050 in. in diameter. Screens made entirely of this uniform perforated material have consistently been shown by test to have less high-frequency attenuation than the losses permissible for an efficient sound screen according to SMPTE recommendations. As a matter of fact, this uniform perforation pattern is commonly used by several screen manufacturers.

However, on the side portions of the Snowhite Evenlite screen where the illumination is lowest there are no perforations. Between the center portion and each side portion of the screen is a gradational perforation area in which the perforations per square inch in a transverse direction decrease in number, as well as in diameter, until they are eliminated entirely. Thus there is a gradual transition from center to side portions from a perforated to an unperforated surface, and the change is made sufficiently gradual to be entirely imperceptible to the eye in the reflected light. At the same time, because the light reflection is reduced at the center of the screen where the illumination is highest, the brightness appears even over all portions of the screen surface.

The Snowhite Evenlite screen is constructed of vertical panels of screen material. A screen 25 ft wide, for instance, requires a total of seven panels to make up the full 25-ft width of the screen, all, of course, of the same screen material but of three types, either uniformly perforated, gradationally perforated or unperforated, sewn together in proper arrangement to meet design specifications. The gradationally perforated panels actually include uniform perforations along a 6-in. width on one side of the panel for matching with the center panel. There is also a 4-in. width on the opposite side of the panel, having no perforations for matching with the unperforated outer portions of the screen.

Thus the area of each of the two gradationally perforated portions in any screen is only 40 in. times the screen height. The uniformly perforated center area consists of the one 50 in. wide panel plus the two 6-in. widths in the matching areas of the gradational panels, times the screen height. Each unperforated area is always equal to one-half the screen width less 71 in., all times the screen height. These unperforated portions comprise equal panels of required widths to complete the full screen dimensions.

As the width of the combined uniform and gradational areas is always 142 in., the larger the screen dimensions, the greater will be the unperforated area.

The particular screen referred to, having a width of 25 ft, actually has an unperforated area 52.7% of the total area, and the uniformly perforated area is only 20.7% of the total area. The gradational area is 26.6%. For a picture size of 29 ft 9 in. by 41 ft, the unperforated area would be 71% of the total area.

Electrical Testing Laboratories have reported the reflectance of the uniformly perforated material used for the center panel of the Snowhite Evenlite screen to be 80.5%. Since the perforation area is 8%, a loss in light passing through these perforations is limited to 8%; therefore, the unperforated area of the same screen material has a reflectance 8% higher, or 86.9%. This is believed to be the highest reflectance yet obtained from a white matte sound motion picture screen. But the main point is that the reflectance of this screen varies by design between the limits of 80.5% and 86.9% in such a manner that, were the illumination of this screen uniform over the entire area, the brightness in the side portions would be 8% higher than at the center.

No attempt has been made for gradational perforations in this screen in a vertical direction, partly because of manufacturing considerations, but principally because such a refinement would be negligible in the apparent uniform brightness of the picture image. This fact is illustrated by the brightness measurements previously given for the screen 25 ft wide. The height of this screen is 18 ft 3 in. One half the height is 9 ft 1½ in. The brightness at a point 8 ft from the center was 8.1 ft-L as compared to a brightness of 9.6 ft-L at the center. It is evident from this data that the distribution of light intensity at a point approximately one foot from the top or bottom edge of the picture area was actually 84.2% of the intensity at the center, whereas at the sides of the screen the distribution was only 64.5%.

There is another factor which minimizes the effect of the ratio of top or bottom edge-to-center light. In the ordinary installation the projection when viewed in elevation is at an angle to the entire screen, and the viewing angle from an optimum seating area is less at the bottom of the screen than at the top. Therefore the difference in angularity and the consequent difference in illumination between the top and bottom of the screen is less noticeable than from the center to side por-

tions. The problem, of course, is to obtain as good a corner-to-center light ratio as possible. The Evenlite screen, having no perforations in the corners or sides, and a maximum permissible perforation area in the center, effectively accomplishes a practical solution to the problem.

The Snowhite Evenlite screen, installed in any theater, serves as a practical illustration of the fact that screens having properly designed perforation patterns and used under recommended viewing conditions have no detrimental effect whatsoever on the quality of the reflected picture. Here on a single screen surface a direct comparison can readily be made of the definition of the picture image reflected from the perforated and unperforated areas of the screen.

Though this paper is intended primarily to offer a practical solution to the screen illumination problem, the results of other tests made by Electrical Testing Laboratories are of interest when compared with ASA specifications (American War Standards Z52.45–1945 and Z52.46–1945), verifying that no sacrifices in desirable characteristics have been necessary or have been made in the development of this screen. The whiteness ratio is 92½%. Brightness at 1.5° angle of observation of the uniform perforated material is 87.5%, with a gradual dropping off to only 78% at 60° angle of observation. These tests, together with the exceptionally high reflectance and sound transmission characteristics previously referred to, combine in one screen all of the desirable qualities of both a uniformly perforated and an unperforated sound screen. What is most important, however, is that the Snowhite Evenlite screen, in appreciably compensating for uneven illumination, does a better job as a sound motion picture screen than is possible with other types of screens.

References

1. "Report of the Projection Practice Committee," *Jour. SMPE,* vol. 31, pp. 482–483, Nov. 1938.
2. "Screen brightness report," *Jour. SMPE,* vol. 27, pp. 127–139, Aug. 1936.
3. A. A. Cook, "Review of projector and screen characteristics and their effects upon screen brightness," *Jour. SMPE,* vol. 26, pp. 522–531, May 1936.
4. A. C. Hardy, "The optics of motion picture projectors," *Jour. SMPE,* vol. 14, pp. 309–317, Mar. 1930.
5. A. C. Hardy, "The distribution of light in optical systems," *J. Frank. Inst.,* vol. 208, no. 6, p. 779, Dec. 1929.
6. D. B. Joy and A. C. Downes, "Characteristics of high-intensity arcs," *Jour. SMPE,* vol. 14, pp. 291–301, Mar. 1930.
7. H. Kellner, "Absorption and reflection losses in motion picture objectives," *Trans. SMPE,* no. 11, pp. 74–78, Oct. 1920.
8. W. B. Rayton, "The effect of aperture lenses on illumination," *Jour. SMPE,* vol. 23, pp. 309–317, Dec. 1934.
9. H. M. Wilcox and L. W. Conrow, "Some technical aspects of theater operation," *Jour. SMPE,* vol. 23, pp. 340–341, Dec. 1934.

General References

"Report of Projection Screens Committee," *Jour. SMPE,* vol. 17, pp. 437–448, Sept. 1931.

L. A. Jones and M. F. Fillins, "Reflection characteristics of projection screens," *Trans. SMPE,* no. 11, pp. 59–73, Oct. 1920.

M. Luckiesh and F. Moss, "The motion picture screen as a lighting problem," Jour. SMPE, vol. 26, pp. 578–591, May 1936.

"Report of the Projection Screens Committee," *Jour. SMPE,* vol. 18, pp. 242–252, Feb. 1932.

"Report of Committee on Screen Brightness," *Jour. SMPE,* vol. 50, pp. 260–273, Mar. 1948.

Three New Standards

Three recently approved American Standards appear on the following pages:

1. Cutting and Perforating Dimensions for 32-Mm on 35-Mm Motion Picture Negative Raw Stock, PH22.73-1951
2. Zero Point for Focusing Scales on 16-Mm and 8-Mm Motion Picture Cameras, PH22.74-1951 (Revision of American War Standard Z52.51-1946)
3. Mounting Threads and Flange Focal Distances for Lenses on 16-Mm and 8-Mm Motion Picture Cameras, PH22.76-1951 (Revision of American War Standard Z52.50-1946)

The first standard was developed by the Film Dimensions Committee and first published as a proposal in February 1949.

The reason for the existence of this type of film (35-mm film with 32-mm perforations) is that it can be processed on 35-mm sprocketless developing machines with consequent saving in equipment. This film is commonly used for sound recording and reduction negatives. The negative thus made is printed in the usual fashion. In general, this 32-mm on 35-mm film is not used for release purposes. However, the fact that people other than manufacturers can perforate 35-mm film in this way has led to some concern. If 35-mm nitrate film were to be perforated with 32-mm perforations, it might later be slit to 16-mm size and be used in projection equipment. The standard, therefore, includes the proviso: "This film should not be made on nitrate base because if this material were slit to 16-mm it might be used on a projector with consequent danger of fire."

No proviso of this sort has been indicated in other standards because it is an unwritten law in film-manufacturing companies that no nitrate-base film should ever be slit to 8-, 16-, or 32-mm widths. The manufacturers do, however, slit both nitrate and acetate film to 35-mm dimensions. Other film users sometimes buy unperforated film and perforate it as they see fit. It was thought, therefore, that special attention should be called to the danger that might result if nitrate film were perforated to any dimensions that might make it usable on 16-mm projectors.

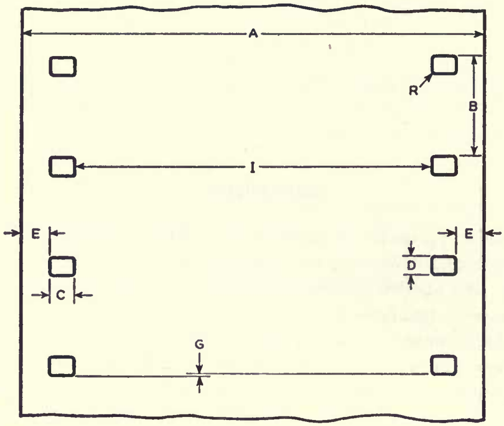
The other two standards resulted from the work of the 16-Mm and 8-Mm Committee in reviewing and revising two War Standards, Z52.50-1946 and Z52.51-1946. The revisions in both standards consisted chiefly in making them apply to 8-mm as well as 16-mm cameras.

American Standard

Cutting and Perforating Dimensions for 32-Millimeter on 35-Millimeter Motion Picture Negative Raw Stock

ASA
Reg. U. S. Pat. Off.
PH22.73-1951

*UDC 778.58



Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.98 ± 0.025
B*	0.300 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
E	0.096 ± 0.002	2.44 ± 0.05
G	Not > 0.001	Not > 0.025
I	1.041 ± 0.002	26.44 ± 0.05
L†	30.00 ± 0.03	762.00 ± 0.76
R	0.010 ± 0.001	0.25 ± 0.03

These dimensions and tolerances apply to the material immediately after cutting and perforating.

*In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 inch and should be as much smaller as possible.

†This dimension represents the length of any 100 consecutive perforation intervals.

Approved May 9, 1951, by the American Standards Association, Incorporated.
Sponsor: Society of Motion Picture and Television Engineers.

*Universal Decimal Classification

APPENDIX

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

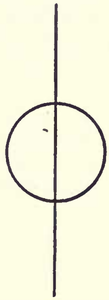
This kind of 32-mm film is made on 35-mm stock so that it may be processed on 35-mm sprocketless negative developing machines.

This film should not be made on nitrate base, because if this material were slit to 16 mm it might be used on a projector with consequent danger of fire.

American Standard **Zero Point for Focusing Scales on 16-Millimeter and 8-Millimeter Motion Picture Cameras**	ASA Reg. U. S. Pat. Off. **PH22.74-1951** Revision of Z52.51—1946 *UDC 778.533.25

1. Focusing scales for 16-millimeter and 8-millimeter motion picture cameras and associated lenses shall indicate object distances measured to the film plane; *i.e.*, the zero point for the focusing scale shall be in the plane of the film.

2. An index mark to indicate the film plane shall be placed on the outside of the camera. This mark shall consist of a circle crossed by a line having a length of between two and three times the diameter of the circle (see illustration below). The line shall be in the plane of the film within 0.040 inch.



Note: One way to distinguish focusing scales made in accordance with this standard is to have the words "From Film" appear after the word "Feet" or other unit designation.

Approved May 9, 1951, by the American Standards Association, Incorporated.

Sponsor: Society of Motion Picture and Television Engineers.

*Universal Decimal Classification

American Standard

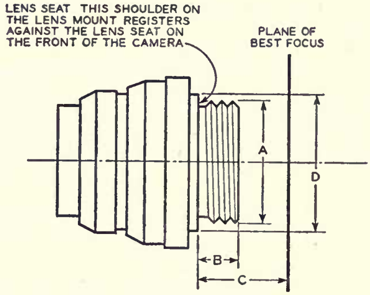
Mounting Threads and Flange Focal Distances for Lenses on 16-Millimeter and 8-Millimeter Motion Picture Cameras

ASA
Reg. U. S. Pat. Off.
PH22.76-1951
Revision of
Z52.50—1946

*UDC 778.53:771.352

1. Purpose

1.1 The purpose of this standard is to describe the two sizes of screw threads and the related flange focal distances in common use for mounting objective lenses on 8-millimeter and 16-millimeter motion picture cameras. The external thread is on the lens, and the internal thread is in the camera.



Nominal (Major) Diameter of Lens Attaching Thread	Threads Per Inch	Length from Shoulder to End of Thread	Flange Focal Distance	Diameter of Lens Seat
A Inch		B Inch	C Inch	D Inch
0.625	32	0.115	0.484	1.000
1.000	32	0.160	0.690	1.187

2. Dimension A

2.1 The American National Thread Form should be used.

Dimensions and tolerances shall conform to those established for a Class-2 fit by the National Bureau of Standards Handbook, H28, Screw Thread Standards for Federal Services (Section V, Screw Threads of Special Diameters, Pitches, and Lengths of Engagement).

3. Dimension B

3.1 The values given for this dimension in the above table are to be considered as the maximum for the lens; a little additional length, for clearance, should be provided in the camera.

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*Universal Decimal Classification

3.2 With some lenses a section of the mount, with a diameter smaller than the root of the thread, necessarily extends closer to the film than is indicated by the drawing. In those cases, the mechanical clearance in the camera must be determined individually.

3.3 In the past, a number of lenses with the 1-inch thread had a B dimension of 0.187 inch. This is considered to be an obsolete practice.

3.4 Past practice has not been entirely consistent so far as the B dimension of the 0.625-inch thread is concerned; some existing cameras will not accept a thread longer than 0.115 inch; some lenses have been made with a length of 0.120 or 0.125 inch.

4. Dimension C

4.1 This dimension is defined as the distance from the lens seat to the plane of the best photographic image. It should be determined photographically with panchromatic film and with the camera operating normally. Sometimes a compromise is necessary between best central definition and best over-all definition.

4.2 The tolerance acceptable for dimension C is dependent on the depth of focus and on a decision as to what portion of the depth can be used for the focus tolerance. In some cases, the tolerance is very small. For example, with a 25-millimeter f/1.4 lens and a 0.001-inch circle of confusion, the depth of focus is 0.0014 inch; only part of this is available for the sum of the lens and camera focusing tolerances.

5. Dimension D

5.1 The values given in the table are to be considered as the maximum diameter of the seat on the lens; the seat on the camera should provide clearance for these diameters.

5.2 If any part of the lens mount has a larger diameter, it should be checked for mechanical interference with the camera on which it is to be used. Some lenses with the 1-inch thread have been made with a flange diameter of 1.500 inches.

Note: This standard does not apply to continuous-type motion picture cameras because of the type of optical system employed in these cameras.

70th Semiannual Convention

Plans for the fall convention are progressing: Bill Kunzmann has been in Hollywood with Peter Mole, John Frayne, and the other Pacific Coast folks who are making the initial plans and will see the Convention through to a happy conclusion at the Hollywood-Roosevelt, October 15–19. We can rely on them for a well organized program, carefully developed in advance and executed with customary dispatch.

PAPERS

Ed Seeley, Chairman of the Papers Committee, and Fred Albin, Hollywood Program Chairman, have announced the author's form and manuscript deadline which must guide prospective authors in preparing their contributions for the 70th Convention program. By August 1 the buff copy of the author's form is to reach Fred Albin and must include a 50-word abstract that will become part of both the tentative and the final programs.

By August 31 the white copy of the author's form must reach Vic Allen, the Society's editor, at 40 West 40th Street, New York 18, accompanied by two copies of the manuscript and one complete set of illustrations. Fred Albin will begin work promptly on the Convention programs and Vic Allen will prepare manuscripts and illustrations for early consideration by the Board of Editors.

Prospective authors should secure their author's forms and a few suggestions entitled "Hints for SMPTE Authors," prepared by the editors, and any other essential information concerning their part in the forthcoming Convention by writing directly to any of the following:

PAPERS COMMITTEE

Chairman, Edward S. Seeley, Altec Service, 161 Sixth Ave., New York 13

70th Convention Program Chairman: Fred G. Albin, Station KECA-TV, American Broadcasting Company Television Center, Hollywood 27, Calif.

Vice-Chairmen

For New York: W. H. Rivers, Eastman Kodak Co., 342 Madison Ave., New York 17

For Washington: J. E. Aiken, 116 N. Galveston St., Arlington, Va.

For Chicago: R. T. Van Niman, 4441 Indianola Ave., Indianapolis, Ind.

For Los Angeles: F. G. Albin (see above)

For Canada: G. G. Graham, National Film Board of Canada, John St., Ottawa, Canada

For High-Speed Photography: J. H. Waddell, Wollensak Optical Co., 850 Hudson Ave., Rochester, N.Y.

For High-Speed Photography for Los Angeles: Roy L. Wolford, 3434 W. 110th. St., Inglewood 2, Calif.

Committee Members

A. C. Blaney, RCA Victor Div., 1560 N. Vine St., Hollywood 28, Calif.

Richard Blount, General Electric Co., Nela Park, Cleveland, Ohio.

R. P. Burns, Balaban & Katz, Great States Theaters, 177 N. State St., Chicago 1, Ill.

Philip Caldwell, American Broadcasting Co., 6285 Sunset Blvd., Hollywood, Calif.

F. O. Calvin, The Calvin Co., 1105 E. Fifteenth St., Kansas City 6, Mo.

Howard Chinn, Columbia Broadcasting System, 485 Madison Ave., New York 22.

J. P. Corcoran, Twentieth Century-Fox Film Corp., 10201 W. Pico Blvd., Beverly Hills, Calif.

G. R. Crane, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

E. W. D'Arcy, De Vry Corp., 1111 W. Armitage Ave., Chicago 14, Ill.

Farciot Edouart, Paramount Pictures Corp., 5451 Marathon St., Hollywood 38, Calif.

F. L. Eich, Paramount Film Laboratory, 1546 Argyle Ave., Hollywood 28, Calif.

Dudley Goodale, National Broadcasting Co., 30 Rockefeller Plaza, New York 20

Charles Handley, National Carbon Div., 841 E. Fourth Pl., Los Angeles 13, Calif.

R. N. Harmon, Westinghouse Radio Stations, Inc., 1625 K St., N.W., Washington, D.C.
Scott Helt, Allen B. Du Mont Labs., Inc., 2 Main Ave., Passaic, N.J.
C. E. Heppberger, National Carbon Div., 230 N. Michigan Ave., Chicago 1, Ill.
J. K. Hilliard, Altex Lansing Corp., 1161 N. Vine St., Hollywood 38, Calif.
L. Hughes, Hughes Sound Films, 21 S. Downing St., Denver, Colo.
P. A. Jacobson, University of Washington, Seattle, Wash.
William Kelley, Motion Picture Research Council, 1421 N. Western Ave., Hollywood 27, Calif.
E. P. Kennedy, Signal Corps Labs, Fort Monmouth, N.J.
George Lewin, Signal Corps Photographic Center, 35–11 35 St., Long Island City 1, N.Y.
E. C. Manderfeld, Mitchell Camera Corp., 666 W. Harvard St., Glendale 4, Calif.
Glenn Matthews, Research Laboratory, Eastman Kodak Co., Rochester 10, N.Y.
Pierre Mertz, Bell Telephone Labs., Inc., 463 West St., New York 14
James Middlebrooks, American Broadcasting Co., 30 Rockefeller Plaza, New York 20
Harry Milholland, Allen B. Du Mont Labs, Inc., 515 Madison Ave., New York 22
W. J. Morlock, General Electric Co., Electronics Park, Syracuse, N.Y.
Herbert Pangborn, Columbia Broadcasting System, Inc., 6121 Sunset Blvd., Hollywood 28, Calif.
Edward Schmidt, Reeves Soundcraft, 10 E. 52 St., New York 22
N. L. Simmons, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif.
S. P. Solow, Consolidated Film Industries, Inc., 959 Seward St., Hollywood 38, Calif.
J. G. Stott, Du-Art Film Laboratories, 245 W. 55 St., New York 19
W. L. Tesch, Radio Corporation of America, RCA Victor Div., Front and Cooper Sts., Camden, N.J.
S. R. Todd, Consulting Electrical Engineer, 4711 Woodlawn Ave., Chicago, Ill.
M. G. Townsley, Bell & Howell, 7100 McCormick Rd., Chicago 45, Ill.

Engineering Activities

Standardization Facilitated by RCA

The Engineering Committee on Optics under the chairmanship of R. Kingslake has been preparing in recent months a Proposed American Standard for the Aperture Calibration of Motion Picture Lenses. The purpose of this standard is to define a suitable method for the measurement and marking of the transmittance of photographic objectives, so that the user may have a more reliable guide to the exposure resulting from a given lens opening than can be derived from the present-day *f*/numbers.

One very good method for doing this is described in U.S. Patent 2,419,421, "Method of Calibrating Lenses with Respect to Effective Optical Speed," granted to L. T. Sachtleben and assigned to the Radio Corporation of America. The Optics Committee valued this method sufficiently to include it in the present Proposed Standard, even though the patent might have proved a bar to its universal availability, and so to its ultimate acceptance as an American Standard.

Recognizing this situation, the Radio Corporation of America has generously agreed to grant a paid-up license under the patent mentioned for the sum of only \$10.00. This nominal fee makes the calibration method easily available to anyone interested in using the present proposal, and also facilitates the retention of the method in the ultimate American Standard. R. H. Heacock, RCA Product Manager, Theatre Equipment, outlines the following procedure for securing a license under the Sachtleben patent:

"If you will kindly arrange to let me know the full name of the companies interested in a license of this kind together with the name of the State in which the corporation, partnership or proprietorship, as the case may be, is registered and the

address at which the company is located, we would be glad to prepare and forward to them an executed copy of the Agreement.

"We hope that the Industry will be able to make use of this patent to good advantage."

The Engineering Committees of SMPTE are unique in providing opportunity for competitors in commercial life to meet, discuss and resolve technical problems for the common good. The present contribution of the Radio Corporation of America to this cooperative effort is deeply appreciated.—F.T.B.

Inter-Society Color Council

The ISCC color names work is actively in progress and is headed in a somewhat different direction from the work in the two publications recently reviewed (see p. 594 of the May Journal), for instead of keying names to specific samples the ISCC plan is to specify *limits* for color designations. The 1939 report by Judd and Kelley, *Method of Designating Colors*, NBS RP 1239, is out of print; a revision is near completion, and should be published within the next year. It will contain, not only specifications for limits for the color name blocks defined in the report, but in an Appendix the color names used in practically all standard works on color names will be related to the ISCC-NBS names. The revision should be more useful than the original report, and the Government Printing Office found that to be one of its best sellers!—Dorothy Nickerson, Secretary, Inter-Society Color Council, Box 155, Benjamin Franklin Station, Washington 4, D.C.

BOOK REVIEW

Film and Its Techniques

By Raymond Spottiswoode. Published (1951) by University of California Press, Berkeley, Calif. 532 pp. Illustrated by Jean-Paul Ladouceur. 6 × 9 in. Price $7.50.

Here is a book for which there has long been a need. Of books on "the cinema," there is a wide selection from all parts of the world, some written by film makers, most by critics and admirers. The theory and aesthetics of this medium have been well discussed. Raymond Spottiswoode himself, in his earlier book, *A Grammar of the Film*, published during the late thirties, probably carried the analysis of film art into higher and thinner realms than anyone short of Eisenstein.

At the other end of the scale, the literature on the technical and engineering aspects of this complex field has followed many special avenues, none of which is entirely comprehensible to the average film maker or the student of film production. There have been hardly any books on the actual practice of film production. Although the student could read widely about cinema, until now he has been unable to buy a book which would tell him how to make a film.

Written by a film producer (documentary) and directed at the student or the worker in film production, this book goes surprisingly far into a basic technical understanding of such areas as the mechanics, chemistry, and optics of film making, without leaving the non-technical reader behind. It will be immediately adopted as a standard text in film production courses everywhere. The book is excellently illustrated with imaginatively conceived diagrams which in themselves contribute greatly to the reader's understanding of complicated processes.

But its value does not stop there. There are few film makers or technicians whose knowledge of the medium is so comprehensive that they would have little to learn from *Film and Its Techniques*. It is a very smoothly written book, and most readers will probably read it right through. The book contains an excellent 90-page glossary and a book list of almost a hundred volumes on various aspects of film, with a paragraph of evaluation for each. It is a long-awaited and eagerly welcomed book.—Rudy Bretz, Croton-on-Hudson, N. Y.

David Sarnoff Gold Medal Award

Technical contributions to television can now be acknowledged by presentation of this annual award made available this year for the first time by the Radio Corporation of America. Candidates for the first award are now being considered by a five-member committee: Raymond L. Garman, General Precision Laboratory, Inc.; Thomas T. Goldsmith, Jr., Allen B. DuMont Laboratories; O. B. Hanson, National Broadcasting Company; William B. Lodge, Columbia Broadcasting System; and Pierre Mertz (chairman), Bell Telephone Laboratories.

Recommendations will be reviewed at the July 19, 1951, meeting of the Society's Board of Governors and if agreement is reached on a suggested recipient the award will probably be presented at the Wednesday night (October 17, 1951) banquet during the Society's 70th Convention in Hollywood. The following official statement has been extracted from the Society's records.

Name of Award **The David Sarnoff Gold Medal**
To be presented annually to that individual selected by the Society of Motion Picture and Television Engineers who has done outstanding work in some technical phase of the broad field of television *engineering*, whether in research, development, design, manufacture, operation, or in any similar phase of theater television.

Purpose The purpose of this Award is to recognize recent technical contributions to the art of television, and to encourage the development of new techniques, new methods, and new equipment which hold promise for the continued improvement of television.

Eligibility The Award *may* be presented to any qualified person whether or not currently a member of the Society of Motion Picture and Television Engineers.

Award The Award shall consist of a gold medal of suitable design, and may be presented at the Annual Meeting of the Society, together with a bronze replica and a citation, stating the recipient's qualifications.

Qualifications and Procedure for Selecting the Recipient The President of the Society shall, each year, appoint a committee, consisting of a Chairman and four members, each of whom shall be qualified to judge the importance or value of current work in some technical phase of the broad field of television *engineering*, whether in research, development, design, manufacture, operation, or in any similar phase of theater television. The Chairman and members of the committee must be Fellows or Honorary Members or have received previously some formal Society Award.

In selecting a roster of candidates for the Award from whom the recipient shall be chosen, preference shall be given to work having reached completion within the preceding five years. Contributions which have led to greater fidelity in reproduction of an original scene, or to simplification of the processes involved, shall be important considerations. The Award shall be made to a particular individual, and if other persons were concerned with the developments which constitute qualification, the individual shall be considered favorably only if he contributed the basic idea and was intimately concerned with its subsequent development.

A Citation (suitable for display) shall be prepared, outlining in reasonable detail the work of the recipient so that it may be understood by anyone skilled in the art.

If in any year the committee does not consider any recent developments to be adequate qualifications for the Award, it shall recommend that no Award be made.

Recommendations of the committee and a report of its deliberations shall be presented to the Board of Governors three months in advance of the time for presentation.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Baird, Kenneth M., Physicist, National Research Laboratories, Ottawa, Ont., Canada. **(A)**

Bauer, Eldon E., Director, Quality Control, Eastman Kodak Co. **Mail:** 1712 Prairie Ave., Chicago, Ill. **(M)**

Borden, Richard, 16-Mm Film Producer. **Mail:** 1031 Canton Ave., Milton, Mass. **(A)**

Burr, R. Page, Engineer, Research Div., Hazeltine Corp., 58–25 Little Neck Pkwy., Little Neck, L.I., N.Y. **(A)**

Chase, Robert H., Film Production Supervisor, N. W. Ayer & Son, Inc., 30 Rockefeller Plaza, New York 20, N.Y. **(A)**

Christie, Dana B., Cine Sales Representative, E. I. du Pont de Nemours & Co. **Mail:** 3289 N. California Ave., Chicago 18. **(M)**

Cooke, James F., Commercial Motion Picture Producer, Highways Bureau, Portland Cement Assn. **Mail:** 633 Beaver Rd., Glenview, Ill. **(A)**

Cooke, Norman C., University of Hollywood. **Mail:** 1023 N. Edgemont St., Hollywood 29, Calif. **(S)**

Coudereau, Pierre, Architect–Decorator. **Mail:** 27 Rue Auber, Algiers, Algeria, French North Africa. **(M)**

Cromwell, Victor H., Television Technician, Columbia Broadcasting Co. **Mail:** R.D. #1, Darien, Conn. **(A)**

De Lorenzi, Otto, Director of Education & Fuels Consultant, Combustion Engineering – Superheater, Inc., 200 Madison Ave., New York 16, N. Y. **(M)**

Dun, Manne, P.O. Box 4192, Johannesburg, South Africa. **(A)**

Fallon, John, Surgeon, Fallon Clinic. **Mail:** 10 Institute Road, Worcester 2, Mass. **(A)**

Finlay, W. G., Laboratory Technician, African Film Productions, Ltd. **Mail:** P.O. Box 2787, Johannesburg, Transvaal, South Africa. **(A)**

Gellert, Hal, TV Technician, Columbia Broadcasting System, Inc. **Mail:** 585 West End Ave., New York, N. Y. **(A)**

Hall, Edward B., Manager, Informational Films Div., Eastman Kodak Co., 343 State St., Rochester 10, N. Y. **(A)**

Haynie, Donald Bruce, Chemical Engineer, Ansco Div. **Mail:** Box 11464 Briggs Station, Los Angeles 48, Calif. **(A)**

Hilliard, Allen F., Boston University. **Mail:** 210 Bay State Rd., Boston, Mass. **(S)**

Hungerford, E. Arthur, Jr., Television Engineer, General Precision Laboratory, Inc. **Mail:** Campfire Rd., Chappaqua, N.Y. **(M)**

Ilowite, Ralph, Radio-Television Broadcasting Engineer, American Broadcasting Co. **Mail:** 479 Dorchester Rd., Ridgewood, N. J. **(A)**

Kalkowsky, Henry, Hollywood Sound Inst. **Mail:** 839 N. Edgemont St., Los Angeles 27, Calif. **(S)**

Kramer, Vernon W., Assistant Director of Sound, Universal-International Pictures Co. **Mail:** 15441 Sutton St., Sherman Oaks, Calif. **(M)**

Lachman, Edward, President, Lorraine Carbons, Inc. **Mail:** Humphrey Rd., Morristown, N. J. **(M)**

Leonard, Robert A., Cinematographer, Medical College of Alabama, Birmingham, Ala. **(M)**

Mac Dermott, A. P., Co-owner, Industrial Motion Pictures, 1706 E. 38th St., Cleveland, Ohio. **(A)**

Morris, Dwight, Film Producer, Mt. Sequoyah, Fayetteville, Ark. **(M)**

Reingold, Edward, New York University. **Mail:** 485 E. 21 St., Brooklyn 26. **(S)**

Schrier, Eugene, New York University. **Mail:** 5015 Clarendon Rd., Brooklyn 3, N.Y. **(S)**

Soame, Reginald, Director, School of Photographic Arts, Dept. of Education, Province of Ontario. **Mail:** 1720 Avenue Rd., Toronto, Ont., Canada. **(M)**

Srinivasan, C., c/o B. R. Chakravarthi, Judge, Pudukkottai, Madras Province, India. **(M)**

Stone, Leroy S., Electrical Engineer, American Broadcasting Co. **Mail:** 38 E. Third St., New York, N.Y. **(A)**

Stratton, Floyd Grant, High-Speed Specialist, Bell Aircraft Corp. **Mail:** Whitehaven Rd., Grand Island, N.Y. **(A)**

Trouant, Virgil Elmer, Manager, Broadcast Engineering Section, RCA Victor Div. **Mail:** 250 Wayne Ave., Haddonfield, N.J. **(A)**

Ward, Edwin J., Training Assistant, Shell Oil Co. **Mail:** 95 East Poplar St., Zionsville, Ind. **(A)**

Webb, Richard C., Research Engineer, RCA Laboratories. **Mail:** Random Rd., R.D. #1, Princeton, N.J. **(M)**

Whittaker, John R., Colorfilm, Inc., 41-17 Crescent St., Long Island City 1, N.Y. **(M)**

Wolford, Roy L., Supervisor, Engineering Photography, Northrop Aircraft, Inc.

Mail: 3434 W. 110 St., Inglewood 2, Calif. (A)

Woods, L. C. (Bud), Film Producer, Bud Woods Productions, Inc. **Mail:** 1601 S. Boston Ave., Tulsa, Okla. (M)

Zeigler, Carl F., Commercial Films Producer, Educational Films Bureau, Portland Cement Assn. **Mail:** 143 Burton Pl., Chicago 10, Ill. (A)

CHANGES IN GRADE

Percy, Charles H., President, Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill. (A) to (M)

Rafferty, Howard T., Sensitometrist, Cinecolor Corp. **Mail:** 1316 Spazier Ave., Glendale 1, Calif. (A) to (M)

Tompkins, Rutledge B., President, International Projector Corp., 55 La France Ave., Bloomfield, N.J. (A) to (M)

Trevor, Don-Marc, Motion Picture Consultant, DuMont Television Network. **Mail:** 825 W. 180 St., New York 33, N.Y. (A) to (M)

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 32, no. 1, Jan. 1951

Cinerama—Super Movies of the Future (p. 12)

A New Revolving Camera Mount (p. 14) F. Foster

New Technique for "Sync" Sound on Quarter-Inch Magnetic Tape (p. 16) W. D. Fling

vol. 32, no. 2, Feb. 1951

Will There Always be a Need for Carbon Arcs? (p. 50) P. Mole

A Bantam-Weight Camera for Underwater Photography (p. 52) H. S. Moncrief

New Technique for "Sync" Sound on Quarter-Inch Magnetic Tape (p. 53) W. D. Fling

The Practical Use of Latensification (p. 54) P. Tannura

Light Source for TV Newsreel Cameramen (p. 58) B. Berg

Meet the New 70-DL (p. 62) F. Foster

British Kinematography

vol. 17, no. 4, Oct. 1951

Motion Picture Camera Development (p. 105) G. Hill

Measurement of Brightness and Illumination of the Kinema Screen (p. 118) F. S. Hawkins and H. W. W. Losty

Electronics

vol. 24, no. 2, Feb. 1951

Telemetering System for Radioactive Snow Gage (p. 88) J. A. Doremus

International Projectionist

vol. 26, no. 1, Jan. 1951

Carbon Arcs vs. Inkies for Non-Theatrical Projection (p. 13) H. H. Strong

This Mysterious Aerial Image (p. 15) R. A. Mitchell

New Technicolor Lighting System Tested by Top-Flight Cinematographers (p. 20) L. Allen

vol. 26, no. 3, Mar. 1951

New Eastman Identification System for Safety Film (p. 12)

Variable Shutters in 16-Mm Filming (p. 23) J. Forbes

Photographic Journal

vol. 91B, sec. B, no. 1, January–February 1951

Some Factors in Pictorial Reproduction Processes With Special Reference to Television (p. 2) R. G. Hopkinson, R. B. Mackenzie and R. D. Nixon

Proceedings of the I.R.E.

vol. 39, no. 3, Mar. 1951

Television Image Reproduction by Use of Velocity-Modulation Principles (p. 265) M. A. Hannell and M. D. Prince

Use of Image Converter Tube for High-Speed Shutter Action (p. 268) A. W. Hogan

Tele-Tech

vol. 10, no. 4, Apr. 1951

JTAC Color Television System Comparison Table (p. 33)

Color-TV Progress (p. 43)

Tele-Vision Engineering

vol. 2, no. 1, Jan. 1951

Perspective Distortion in TV Pictures (p. 12) E. C. Lloyd

vol. 2, no. 2, Feb. 1951

Perspective Distortion in TV Pictures (p. 18) E. C. Lloyd

The Five-Year Index

FIVE YEARS of the Society's JOURNAL amount to sixty issues in ten semiannual volumes. From January 1946 through December 1950 the contemporary history of both industries served by our Society has been set down. To make this information easy to find takes a lot of indexing plus a lot of packing and poking to package it as neatly as we tried to in what went to you as Part II of your May JOURNAL.

Headquarters put a great deal into the Index—not only to give it some unique features but also to make it as readily useful as possible. We hope you have had a chance to review it and will tell us what you think of it—and also we hope that after you've used it a while you will send in your suggestions and criticisms so they can be hung on the spindle to be handy when 1955 rolls around and we begin packing and poking again.

Journals Out of Stock: The Society's stock of JOURNAL issues for March, Part II, July, August, September, 1949, and February, 1950, has been exhausted as a result of an unexpected increase in demand and the Society's Headquarters is anxious to purchase a stock of each. Members or libraries having extra copies available are invited to send them in. The going price is 75c.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April JOURNAL.

New Products

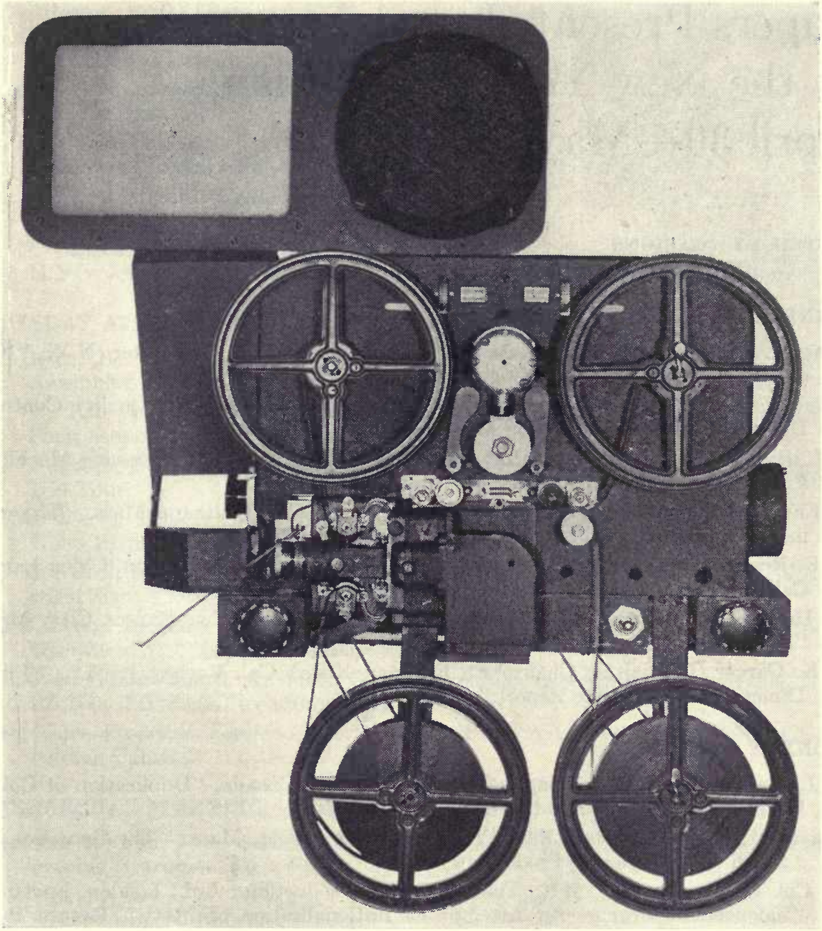
Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

The Metro-Lite Vaudeville is a new spotlight put on the market this year by Genarco, Inc., 36–56 34th St., Long Island City 6, N.Y. It is a high-intensity carbon-arc spotlight which operates at between 60 and 85 amp, 40 to 60 volts d-c. It is used in large theaters, wherever the throw is 75 to 250 ft, with the same rectifier or generator as the projection lamp in the booth. A modern four-lenses optical system combines with an automatic iris to provide, according to the manufacturer, a sharply defined outline with no blurring. The positive 9-mm × 20-in. high-intensity carbon is continuously rotated, and it, with the negative 5⁄16-in. copper-coated high-intensity carbon, is automatically fed by a silent motor. A single wheel automatically focuses the spot, opens the inside iris and controls the size of the spot.

Genarco also manufactures the Metro-Lite, a high-intensity carbon-arc spotlight which operates at 125 amp, 55 to 60 volts d-c. It is used in arenas, very large cinemas, auditoriums or theaters, wherever the throw is 100 to 400 ft.

The Munsell Chart-Photometer is described in a new brochure from Munsell Color Co., Inc., 10 E. Franklin St., Baltimore 2, Md. The chart is an assembly of 11 value-reflectance scales with instructions, and it sells for $15.00.

The system is designed for three illuminants: incandescent light, average daylight and light from blue sky. One of the 11 charts is a special scale of 19 neutrals and the other charts are each for one of the 10 major hues. The brochure continues with an example and explanation of computing reflectance characteristics for the 189 color standards of the Chart-Photometer.



This 16-Mm Double-System Editing Machine for motion picture film and sound track is now being produced by M. W. Palmer, 468 Riverside Drive, New York 27. This editor was designed especially to meet the needs of the professional 16-mm industry.

There are separate film channels—for sound and for picture. Each channel is separately controlled. Either film can be operated independently of the other, or both channels can be interlocked, to make both films run in synchronism.

Composite film can be run by threading through both picture and sound heads, which are spaced properly, to give correct distance between picture and sound. Separate frame and footage indicators are provided, one for each film, and if desired, cutting can be done without marking the film, by notation of the foot and frame number, where the cut is to be made. The machine is furnished with magnetic pickup from 16-mm perforated magnetic film if required. A foot-pedal speed control is provided and there is a reverse switch for operation in either direction.

Papers Presented at the New York Convention, April 30—May 4

LISTED BY SESSIONS

MONDAY AFTERNOON

Henry J. Hood (Committee Chairman), Eastman Kodak Co., Rochester, N.Y., "16- and 8-Mm Motion Pictures Committee Report."

Edgar E. Berger, Du-Art Film Laboratories, Inc., New York, "The Quality Control Department of a Medium Size Motion Picture Laboratory."

F. L. Bray, Du-Art Film Laboratories, Inc., New York, "A New Processing Machine Film Spool for Use With Either 35-Mm or 16-Mm Film."

L. Katz and W. Esthimer, Raytheon Manufacturing Co., Waltham, Mass., "Experiments in High-Speed Processing Using Turbulent Fluids."

H. E. Hewston and Carlos H. Elmer, U.S. Naval Ordnance Test Station, China Lake, Calif., "A Continuous Processing Machine for Wide Film."

W. Hedden, T. Weaver and Lloyd Thompson, The Calvin Co., Kansas City, Mo., "Processing 16-Mm Kodachrome Prints."

E. K. Carver (Committee Chairman), Eastman Kodak Co., Rochester, N.Y., "Film Dimensions Committee Report."

MONDAY EVENING

R. J. Ross, National Film Board of Canada, Ottawa, Canada, "Duplication of Color Images With Narrow Band Filters."

Morton H. Read, Bay State Film Productions, Springfield, Mass., "The Operation of a Small Motion Picture Production Studio."

Lt. Col. G. R. Stevens, O.B.E., Television Film Productions, Ltd., London, England, "Independent Frame—An Attempt at Rationalization of Motion Picture Production."

Herbert Meyer, Motion Picture Research Council, Inc., Hollywood, Calif., "Nonphotographic Aspects of Motion Picture Production."

J. S. Leffen, LCDR., U.S.N., U.S. Naval Photographic Center, Anacostia, D.C., "Experimental Utilization of Television Equipment for Navy Training Film Production."

TUESDAY MORNING

R. L. Garman (Committee Chairman), General Precision Laboratory, Pleasantville, N.Y., "Films for Television Committee Report."

Howard Chinn, Columbia Broadcasting System, New York, "The Over-all Factors in Television Recording Operations."

Kendel Foster, William Esty Agency, New York, "Film Problems from the Advertising Agency Point of View."

Frank LaPore, National Broadcasting Co., New York, "The Distribution of Kinescope Films to Maintain a Television Network."

P. J. Herbst, R. O. Drew and S. W. Johnson, RCA Victor Division, Camden, N.J.' "Electrical Compensation vs. Photographic Masking in the Improvement of Contrast and Detail in Televised Film."

Fred G. Albin, American Broadcasting Co., Hollywood, Calif., "Gray Scale Control in Video Systems."

K. B. Benson and A. B. Ettlinger, Columbia Broadcasting System, New York, "Practical Use of Iconoscopes and Image Orthicons as Film Pickup Devices."

W. D. Kemp, British Broadcasting Corp., London, England, "Television Recording in Great Britain."

F. N. Gillette (Committee Chairman), General Precision Laboratory, Pleasantville, N.Y., "Joint RTMA-SMPTE Television Film Equipment Committee Report."

TUESDAY AFTERNOON

R. Bown, Bell Telephone Laboratories, Murray Hill, N.J., Speech of Welcome to Assembled Group.

M. W. Baldwin, Jr., Bell Telephone Laboratories, Murray Hill, N.J., "Subjective Sharpness of Additive Color Pictures."

A. G. Jensen, Bell Telephone Laboratories, Murray Hill, N.J., Description of Murray Hill Tour.

Pierre Mertz, Bell Telephone Laboratories, Murray Hill, N.J., "Data on Random Noise Requirements for Theater Television."

D. T. Wilber, Allen B. DuMont Laboratories, Clifton, N.J., "The Conversion of Electrical Signals into Visual Information."

E. C. Fritts, Eastman Kodak Co., Rochester, N.Y., "A 16-Mm Projector for Storage Operation With Television Cameras."

Frank N. Gillette and R. A. White, General Precision Laboratory, Pleasantville, N.Y., "A New Television Recording Camera."

John Kiel, Producers Service Corp., Burbank, Calif., "A New 35-Mm Television Recording Camera."

WEDNESDAY MORNING — Two Sessions

Kenneth Shaftan, J. A. Maurer, Inc., Long Island City, N.Y., "Progress in Photographic Instrumentation."

J. W. Beams and J. M. Watkins, University of Virginia, Charlottesville, Va., "A High Constant-Speed Rotating Mirror."

W. L. Hicks and R. L. Wright, Burroughs Adding Machine Co., Detroit, Mich., "Practical Application of High-Speed Photography in Business Machines."

R. V. Bernier, Maj., USAF, Wright-Patterson Air Force Base, Dayton, Ohio, "Three-Dimensional Motion Picture Applications."

W. W. Lozier (Committee Chairman), National Carbon Division, Fostoria, Ohio, "Report on Screen Brightness Committee Theater Survey."

H. J. Benham, RCA Victor Division, Camden, N.J., "Studies and Comparisons of Current Motion Picture Projection Systems for Indoor and Drive-In Theaters."

F. J. Kolb, Jr., and F. Urbach, Eastman Kodak Co., Rochester, N.Y., "Temperature-Sensitive Phosphors for Evaluating Air Jets Designed to Cool Motion Picture Film."

G. Gagliardi, Warner Brothers Theaters, Newark, N.J., and A. T. Williams, Weston Electrical Instrument Co., Newark, N.J., "An Instrument to Measure Total Light Output at the Lens."

Charles R. Underhill, Jr., RCA Victor Division, Camden, N.J., "The Practical Solution to the Screen Light Distribution Problem."

W. G. Hill, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y., "Modified Negative Perforation Proposed as a Single Standard for 35-Mm Motion Picture Film."

R. W. Lavender, Ansco Division, General Aniline & Film Corp., Binghamton, N.Y., "Photoelectric Method for Evaluating Steadiness of Motion Picture Film Images."

WEDNESDAY AFTERNOON — Two Sessions

Alsede W. Hogan, Naval Ordnance Laboratory, Silver Spring, Md., "Use of Image Phototube as a High-Speed Camera Shutter."

S. A. Weinberg, J. S. Watson, Jr., M.D., and G. H. Ramsey, M.D., University of Rochester School of Medicine and Dentistry, Rochester, N.Y., "Cinefluorography, Mechanical Factors and Diagnostic Applications."

Eugene L. Perrine and Nelson W. Rodelius, Armour Research Foundation, Chicago, Ill., "Simultaneous High-Speed Arc Photography and Data Recording With 16-Mm Fastax Camera."

E. M. Lowry, Eastman Kodak Co., Rochester, N.Y., "The Luminance Discrimination of the Human Eye."

David L. MacAdam, Eastman Kodak Co., Rochester, N.Y., "Influence of Color of Surround on Hue and Saturation."

S. D. S. Spragg, University of Rochester, Rochester, N.Y., "Visual Performance on Perceptual Tasks at Low Photopic Brightnesses."

H. L. Logan, Holophane Co., Inc., New York, "Photometric Factors in the Design of Motion Picture Auditoriums."

Sylvester K. Guth, General Electric Co., Cleveland, Ohio, "Surround Brightness: Key Factor in Viewing Projected Pictures."

Benjamin Schlanger and William A. Hoffberg, Theater Engineering and Architecture Consultants, New York, "New Approaches Developed by Relating Film Production Techniques to Theater Exhibition."

THURSDAY MORNING

E. A. Andres, Sr., and H. P. Roganti, Wright-Patterson Air Force Base, Dayton, Ohio, "High-Speed Photography."

Karl Maier, Springfield Arsenal, Springfield, Mass., "A Slide Rule for Analyzing High-Speed Motion Picture Data."

Brian O'Brien, University of Rochester, Rochester, N.Y., "A Printer for Image Dissection Camera Negatives."

Robert Rice, University of North Carolina, Chapel Hill, N.C., "A Study of Flames."

John H. Waddell (Committee Chairman), Wollensak Optical Co., Rochester, N.Y., "High-Speed Committee Report."

THURSDAY AFTERNOON

Samuel R. Todd, Board of Examiners, City of Chicago, Chicago, Ill., "Safety Requirements in Projection Rooms and Television Studios."

Otto H. Schade, Tube Dept., RCA Victor Division, Harrison, N.J., "A New System of Measuring and Specifying Image Definition."

H. G. Kobrak, M.D., University of Chicago, Chicago, Ill., "Auditory Perspective."

E. Arthur Hungerford, Jr., General Precision Laboratory, Inc., Pleasantville, N.Y., "Techniques for Producing Electronic Movies."

Richard Blount (Committee Chairman), General Electric Co., Nela Park, Cleveland, Ohio, "Television Studio Lighting Committee Report."

FRIDAY MORNING

J. R. Montgomery, J. R. Montgomery Engineering Co., Chicago, Ill., "Tape Transport Theory—Speed Control."

George Lewin, Signal Corps Photographic Center, Long Island City, N.Y., "Special Techniques in Magnetic Recording for Motion Pictures."

George Lewin, Signal Corps Photographic Center, Long Island City, N.Y., "Synchronous Quarter-Inch Magnetic Tape for Motion Pictures."

Leslie I. Carey and Frank Moran, Universal-International Pictures Co., Inc., Universal City, Calif., "Push-Pull Direct-Positive Recording—An Auxiliary to Magnetic Recording."

Robert Herr, Minnesota Mining and Manufacturing Co., St. Paul, Minn., "Ferrite Materials for Magnetic Heads."

FRIDAY AFTERNOON

W. W. Wetzel, B. F. Murphey and R. Herr, Minnesota Mining and Manufacturing Co., St. Paul, Minn., "The Mechanism of High-Frequency Bias in Magnetic Recording."

George W. Colburn, George W. Colburn Laboratories, Chicago, Ill., "Editing Quarter-Inch Synchronous Magnetic Tape."

E. E. Masterson, F. L. Putzrath and H. E. Roys, RCA Victor Division, Camden, N.J., "Magnetic Sound on Edge-Coated 16-Mm Film."

James A. Larsen, Academy Films, Hollywood, Calif., "Improved Kodachrome Sound Quality With Supersonic Bias Technique."

C. H. Evans and J. F. Finkle, Eastman Kodak Co., Rochester, N.Y., "Sound Track on Eastman Color Print Film."

R. T. Van Niman (Subcommittee Chairman), 4441 Indianola Ave., Indianapolis, Ind., "Report from Phototube Subcommittee of Sound Committee."

Meetings of Other Societies

American Physical Society, June 25–28, Vancouver, Canada

American Institute of Electrical Engineers, June 25–29, Toronto, Canada

Illuminating Engineering Society, Aug. 27–30, Washington, D.C.

Biological Photographic Association, 21st Annual Meeting, Sept. 12–14, Kenmore Hotel, Boston, Mass.

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

Acoustical Society of America, Oct. 23–25
Optical Society of America, Oct. 23–25
Society of Rheology, Oct. 24–26
American Physical Society, Oct 25–27
American Association of Physics Teachers, Oct. 25–27

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THROUGH the cooperation of the Library Binding Institute, an organization of binderies which specializes in binding publications into volumes, arrangements have been made to give information and assistance to Society members who want to have their JOURNALS bound. This work may be done in accordance with standards of materials and construction required for durability, service and accessibility by college, reference and public libraries. The American Library Association and the Library Binding Institute have cooperated in promulgating "Minimum Specifications for Class A Library Binding" based on research and production and performance experience.

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As Part II of this issue, there is appended a Volume Title Page with Volume Contents to go at the front of the volume when bound, and the Volume Index to go at the back.

A microfilm edition of the JOURNAL may also be obtained by members or subscribers by direct correspondence with University Microfilms, 313 North First St., Ann Arbor, Mich.

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